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FOREST PLANTING IN THE LAKE STATES

By

JOSEPH KITTREDGE, Jr., Silviculturist

Lake States Forest Experiment Station, Branch of Research, Forest Service

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By Joseph Kittredge, Jr., *Silviculturist, Lake States Forest Experiment Station, Branch of Research, Forest Service*

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INTRODUCTION

IMPORTANCE OF FOREST PLANTING IN THE LAKE STATES

It is estimated that there is in Minnesota, Wisconsin, and Michigan a total area of about 20,000,000 acres of land better suited to the growing of forests than to any other purpose and which because of repeated logging, burning, or both now bears no valuable forest growth. Most of it must be planted before forests will grow upon it. The enormous size of this denuded area, about one-third of the total forest land of the region, is the strongest evidence of the necessity for reforestation.

What reforestation has as yet been done represents only a start in the right direction. Up to and including 1926, only 0.33 per cent of the area had been planted. Even at the rate of 15,000 acres a year, the area planted in 1926, more than 1,300 years would be required to reforest the 20,000,000 acres. No region can afford to have so large an area of land lying idle for centuries. But to remedy this situation a large and continued expansion of forest planting by all agencies in each of the States is essential.

The area in need of reforestation undoubtedly includes some lands on which more or less natural tree growth has already started. As the fire-protection work of the States and other organizations becomes more effective the scattered seedling trees escape destruction and live, grow, and increase in number. If these lands were to be protected for a sufficient period, a large part of them undoubtedly would restock with trees naturally, although chiefly with inferior kinds and those of low value. Here better fire protection will help and is essential, but it can not be said to offer a solution for all these idle lands. The process of natural restocking would be so slow that the owners, whether public or private, could better afford to plant the lands than suffer the loss from holding them unproductive for so many years. Under present conditions any decrease in the area in need of planting as a result of natural reforestation tends to be equaled or exceeded by the areas cut over and burned annually.

THE REGION AND ITS PHYSICAL CHARACTERISTICS

The land in need of reforestation to which this bulletin applies (fig. 1), lies in the northern two-thirds of the States of Michigan, Wisconsin, and Minnesota. It includes the area north of a line from Saginaw Bay, in Michigan, westward through Sheboygan, Wis., thence northwestward through St. Croix Falls, Wis., to Wadena, Minn., and northward to Thief River Falls and the Canadian boundary. This is the region from which the famous white pine lumber of the Lake States came, and which more recently has produced and continues to produce a large quantity of sugar maple, eastern hemlock, basswood, yellow birch, beech, spruces, balsam fir, and jack pine. It does not include the southern parts of the three States, where oaks, hickories, and maples are the characteristic trees usually occurring as small woodland areas on farms. The planting problems of the southern area of the Lake States are not the same as those of the north; they have already been covered to some extent in several published reports (*2*,[1] *6*, *13*, *14*, *32*, *33*, *34*, *38*, *60*, *65*, *68*, *69*, *78*).

The climate, topography, and soil, although varying locally, are for the region as a whole comparably uniform. The precipitation ranges from about 25 inches annually in parts of lower Michigan and western Minnesota to 40 inches in northwestern Wisconsin. For most of the region it is between 30 and 35 inches annually, of which 20 to 25 inches falls during the growing season from April 1 to September 30. The snowfall increases northward and is noticeably heavier and remains on the ground longer in the region of Lake Superior and in northern Minnesota than elsewhere in the region.

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[1] Reference is made by italic numbers in parentheses to literature cited, p. 83.

For example, the annual snowfall at Marquette, Mich., is 117 inches, as compared with 44 inches at Saginaw. The irregular occurrence most commonly in spring and fall, of drought periods of 10 to 20 or 30 days, with little or no rain, is characteristic. This is apparently a more important factor in forest planting than the quantity or distribution of annual or seasonal precipitation in the region.

Temperatures tend to be lower in the northwestern part than in the southeastern part of the region. The annual average at International Falls, Minn., is 35° F., as compared with 46° at Saginaw, Mich. Maxima of 90° to 100° are recorded throughout the region almost every summer. The effects of different temperatures, however on the length of the growing season, on the amount of frost damage, or on the damage from excessive heating of the seedlings do not appear to be noticeably different in any part of the region.

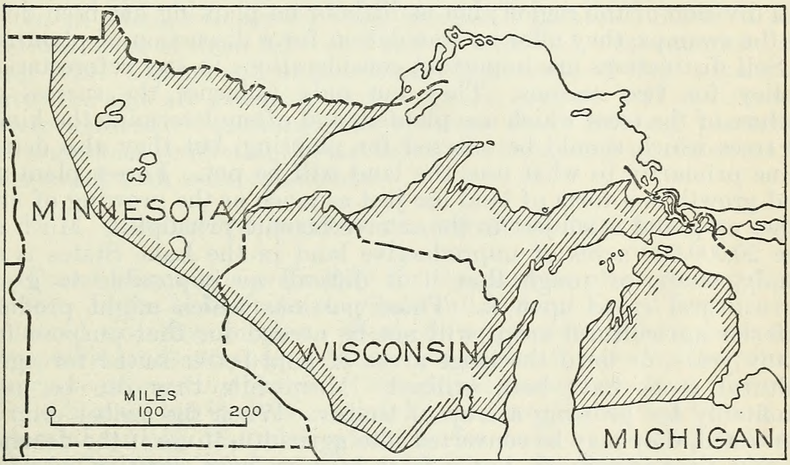

FIGURE 1.—The northern Lake States region

Three zones of natural forest growth may be distinguished: (1) The spruce-fir forests of the north, (2) the maple-basswood-hemlock and Norway pine-jack pine forests of the central zone, and (3) the white pine-oak-maple forests of the southern zone. The tree species which have been planted most extensively and which are best suited for planting in the region as a whole, succeed in all three of these zones.

The topography of the region varies locally, but does not serve to distinguish any one large portion from another, with the possible exception of the triangular area in northeastern Minnesota where in many places the bedrock is exposed or is covered with only a thin layer of soil. The rest of the region is overlaid by comparatively thick glacial deposits, which form the confusing array of hills and valleys, plains, ridges, swamps, and lakes characteristic of the region, and which have much to do with the character of the soil.

Differences in the soil underlie the differences in the natural forest growth and are equally important in forest planting. The soils vary widely, from the droughty dune, beach, and outwash sands to the clays of the old lake beds and the mucks and peats of the swamps.

Most of the soils of the area in need of reforestation, however, are sandy or loamy and often also rocky or gravelly. Many soil types have been recognized in the soil surveys, but in more detail than is necessary in discussing forest planting on the basis of experience to date. The different types may be found so close together in any part of the region that their differences serve rather as the basis for local distinctions than for broad treatment, as between north and south or east and west. Broad distinctions will be made, however, between the dry, sandy soils occupied naturally by jack pine or oaks, at one extreme, and the loamy soils at the other with their better conditions of moisture and fertility. The heavier soils are or have been characterized by natural growth of northern white pine, sugar maple, basswood, yellow birch, beech, eastern hemlock, white spruce, or aspen. The swamps, with their natural growth of black spruce, tamarack, northern white cedar, and other species, form a separate soil division of the region; but as little or no planting has been done in the swamps, they offer no foundation for a discussion of planting.

Soil distinctions are important considerations in any reforestation policy for two reasons. They not only influence the success or failure of the trees which are planted, and often determine the kinds of trees which should be selected for planting, but they also determine primarily to what uses the land will be put. Forest planting and growth is a form of land use just as much as the growing of any other crop and is subject to the same economic principles. Much of the 20,000,000 acres of unproductive land in the Lake States is so sandy, stony, or rough that it is difficult or impossible to grow agricultural crops upon it. Those portions which might produce inferior agricultural crops will not be needed for that purpose for many years, or until the large areas of land better suited for agricultural crops have been utilized. Meanwhile they can be used profitably for growing a crop of timber. When the timber crop is harvested, they may be converted into agricultural use if the demand at that time justifies it, but it is at least an open question whether such lands may not always be more profitable for timber growing.

THE ESSENTIALS OF A PLANTING POLICY

The fact that the present reforestation programs are inadequate to make productive in any reasonable period of time the 20,000,000 acres of denuded forest land in the Lake States is sufficient evidence of the need of planting and of a reforestation policy for these lands. (Pl. 1, A.) The area as a whole, or even the area in each State, is so large that no one agency, be it State, Federal, or private, can solve the problem alone. Any successful policy must provide for action individually and cooperatively by all three agencies.

The essentials of a planting policy are: (1) A survey of lands in need of planting to determine area, location, ownership, condition, and value for planting; (2) effective fire protection for lands to be planted; (3) the planting of publicly owned lands by public agencies; (4) the expansion of public-planting programs, including the acquisition of additional lands to be planted; and (5) encouragement of counties, towns, and private agencies in forest planting by the Federal and State Governments, through advice to owners, the distribution of planting stock, possible modification of taxes on land devoted to the growing of forests, provision of cheap, long-time credit, and cooperative arrangements between owners and the States.

For the formation of such a policy public interest in reforestation and timber growing is not lacking; it has, indeed, increased rapidly in the last few years. A widespread sentiment is favorable to reforestation, but it has not yet crystallized. Perhaps the principal need is for planting facts upon which to base a policy. This study of forest planting in the region has therefore been undertaken with the purpose of furnishing such information. An attempt will be made to answer such questions as these: What kinds of lands should be planted, and what kinds of lands, if any, should not be planted? What kinds of trees are most likely to succeed on the different soils? What sizes of trees should be used for planting? When should the trees be planted? How should they be planted? What kinds of trees are most profitable to plant? Does planting pay?

In an attempt to answer these questions, about 400 different plantations, most of them between 5 and 20 years old, were examined during 1924. Counts and measurements were made of their success and growth, and all available facts of their history and environment were gathered.[2] Although the evidence from different plantations is sometimes conflicting, nevertheless the foregoing questions may be answered with some confidence.

HISTORY OF FOREST PLANTING IN THE REGION

Forest planting is ordinarily for the purpose of producing timber crops. In the Lake States the State and Federal Forest Services have planted with this purpose. Most of the plantations have been made on public lands set apart as State or national forests for the primary purpose of growing timber. Considerable areas have been planted in solid blocks, and there is every evidence that they will provide a substantial supply of timber products for local or general industries when the trees reach merchantable size. In addition to planting State-owned lands, the States have raised forest planting stock in large quantities for distribution at cost to companies and individuals for planting on private lands.

Planting by private owners, whether companies or individuals, has usually been on a small scale, however, and in the nature of trials of feasibility rather than of serious attempts to provide a future supply of timber. There is each year an increasing demand for forest planting stock, but it comes chiefly from farmers and small landowners who plant only a few hundred trees or at most a few acres. These small plantings are desirable and should be encouraged, but with a few exceptions they have not been continued long enough or developed on a large enough scale to provide for future timber supplies in workable units or to maintain a supply of raw material for woodworking plants. Even companies with large investments in wood-using plants, like the pulp and paper mills which require a continued supply of timber for a long period of years to justify their investment, have not yet undertaken forest planting operations for timber production.

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[2] The cooperation of the many persons who willingly assisted and made possible this part of the study is gratefully acknowledged. Particularly, mention should be made of the help of F. G. Wilson, of the Wisconsin Department of Conservation; of Marcus Schaaf, State forester of Michigan; of the custodians of the State forests in Michigan; of the members of the Minnesota Forest Service and of the national forests in Michigan and Minnesota. Special acknowledgment is also made to H. C. Hilton, formerly supervisor of the Michigan National Forest, whose unpublished manuscript of 1920 on forest planting on the sandy plains of the Lake States has been helpful in the preparation of this report, and to Raphael Zon, whose inspiring advice and encouragement throughout the work have been invaluable.

AREAS PLANTED

The first forest planting in the northern part of the Lake States was done in experimental plantations established in 1888 at Grayling, and Oscoda, Mich., by the Michigan Agricultural College, and at Grand Rapids, Minn., in 1898, by the Minnesota Agricultural College. A few private companies or individuals did a little forest planting in 1903, 1904, and 1905. A little planting was done on the Higgins Lake State Forest in Michigan as early as 1904. In 1910 and 1911 the State of Wisconsin began planting operations, and the Federal Government made a similar beginning on the national forests in Michigan and Minnesota. At the same time Michigan expanded its planting program. But the main part of the planting has been done since 1915.

The total area planted up to and including 1926 in the three Lake States, excepting the prairie region of southern and western Minnesota, was about 74,000 acres. Of this 39,000 acres were planted by the States, 27,000 by the Federal Government on the Michigan and Minnesota National Forests, and possibly 8,000 by private owners. The State of Michigan alone has planted nearly 34,000 acres on the State forests, while Wisconsin and Minnesota have planted 3,300 and 2,000 acres, respectively. The area planted annually has increased. In 1923, 4,000 acres were planted; in 1924, the total exceeded 10,000; in 1925 it almost reached 12,000, and in 1926, 15,000 acres were planted.

KINDS OF TREES PLANTED[3]

If the total area planted in the northern part of the Lake States be subdivided on the basis of the proportion of different kinds of trees used, it appears that 60 per cent has been planted to Norway pine, 25 per cent to northern white pine, 7 per cent to jack pine, 5 per cent to Scotch pine, 1 per cent each to Norway and white spruce, and 1 per cent to all other kinds. These other kinds include European larch, Austrian pine, western yellow pine, red oak, white ash, Douglas fir, northern white cedar, basswood, tamarack, sugar maple, lodgepole pine, box elder, green ash, Russian poplar, paper birch, red maple, hardy catalpa, black locust, balsam poplar, eastern cottonwood, silver maple, beech, American elm, eastern red cedar, red, blue, and Engelmann spruce, honey locust, western white pine, noble fir, black cherry, and yellow birch. Black walnut and yellow poplar are not hardy in the Northern Lake States, although they do well in the southern parts of Michigan and Wisconsin. None of these species has been tried out thoroughly under different conditions of soil and site, so that it can not be said finally that any of them are unsuited to planting in the region. On the other hand, the only ones which have so far proved successful in the northern part of the region, as judged by survival and growth, are Norway, northern white, jack, and Scotch pine, Norway and white spruce, eastern cottonwood, Russian poplar, box elder, and white and green ash. The four latter species have been successfully planted only where they received cultivation at the time of and after planting, and it is not certain that they would be successful without some cultivation.

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[3] The scientific names of the species mentioned in this bulletin will be found listed in the appendix.

Indications of the relative desirability of 27 different kinds of trees for planting under conditions similar to those in the Northern Lake States, obtained from plantations 38 and 45 years old at Ottawa and Guelph, Ontario, are given in the tabulation below. The plantings at Ottawa were described and preliminary conclusions were drawn in 1903 (*46*). The trees at both places were planted in good soils varying from sandy to clay loam and the soils were cultivated before and after planting.

Most successful:	Moderately successful:	Unsatisfactory:
European larch.	Red oak.	Silver maple.
Scotch pine.	American elm.	Black locust.
White spruce.	Bur oak.	Butternut.
Austrian pine.	Balsam fir.	Black walnut.
Paper birch.	Sugar maple.	Basswood.
Norway spruce.	Yellow birch.	Box elder.
Northern white pine.	Northern white cedar.	Winged elm.
Green ash.	Black cherry.	Eastern hemlock.
White ash.		Hardy catalpa.
		Sycamore maple.

On these good, cultivated soils all the most successful kinds—and of the moderately successful, red oak, American elm, and sugar maple—made excellent growth. Austrian pine, northern white pine, and Norway spruce had the largest diameters, and paper birch, Norway spruce, and European larch the greatest heights at Ottawa. European larch excelled in both diameter and height growth at Guelph. Unfortunately Norway and jack pine were not included in these plantations. The relative success of the species in the different groups is likely to be applicable in the selection of species to plant in the Lake States, provided the plantations are on good soils and are cultivated. Furthermore, it may be safely concluded that the species which proved unsatisfactory under these favorable conditions at Ottawa and Guelph are not likely to do well in the northern Great Lakes region.

Seventy-five per cent of the planting in the Lake States has been done on the sandy soils which are naturally droughty and on which repeated fires have destroyed the surface layer of leaf litter and exposed the soil to the most severe evaporation and heating. The available planting data may thus be considered incomplete to the extent that they give relatively little evidence of the possibilities on the heavier loamy soils for trees that have failed on the sands.

SURVIVAL OF DIFFERENT KINDS OF TREES

If the results of planting are analyzed on the basis of the percentage of trees still living in the plantations, it is found that for all kinds and in all three States there are only 14 per cent or 1 in 7 of the plantations in which less than 30 per cent of the trees are living and which must therefore be considered unsatisfactory. The percentages of the different species that have failed in the plantations as a whole are as follows: Norway spruce, 7 per cent; northern white pine, 8 per cent; Scotch pine, 10 per cent; jack pine, 12 per cent; Norway pine, 19 per cent; white spruce, 45 per cent;[4] and European larch, 50 per cent.

Expressed in another way, the average survival for 145 Norway pine plantations was 56 per cent; for 123 northern white pine plantations, 57 per cent; and for 67 jack pine plantations, 56 per cent.

PRESENT PLANTING PRACTICE

Past experience in forest planting in the Lake States is sufficient to demonstrate satisfactory technic. Differences in planting practice between the different organizations now engaged in forest planting in the region are due to the fact that two or three methods give closely comparable and satisfactory results. The basis of planting technic is a thorough understanding of species and seasons for planting, the size and age of the trees to be planted, the best methods of planting, the space between the trees or the number of trees which should be set out to the acre, and the species which should be planted together.

These older plantations, with an average of 56 per cent of the trees living, were set out when planting methods were not as well developed as they have been more recently. On some 5,000 acres of the Huron National Forest and on 14,000 acres of the State forests in Michigan more recent plantations have an average survival of 85 per cent. This figure undoubtedly represents more accurately the degree of success which is being attained and which may be expected in forest planting in the northern Lake States.

DIRECT SEEDING

The sowing of seed in seed spots or broadcast on the planting sites (*20*) has been thoroughly tested in the Lake States. About the time the first plantings were made, direct seeding of Norway, northern white, and Scotch pine and red oak was tried, but without sufficient success to justify its continuance. On some plantations a few trees survived, but most of them were complete failures. The poor results in Michigan (*52*) were attributed to the effects of hot, dry weather upon the small seedlings on the open sandy soils. Rodents were apparently not responsible, since seed treated with substances poisonous to rodents gave no better results than untreated seed. As a result of these failures, direct sowing in the region has been abandoned as a means of establishing plantations.

There are examples, however, in this and adjacent regions of successful reforestation by sowing the seed directly on the planting site. At the Petawawa Forest Experiment Station in Ontario northern white pine seed was sowed in spots under three 40-year-old stands having, respectively, 1,715, 1,278, and 600 aspen, paper birch, and other trees to the acre. After two years there were, respectively, 320, 1,600, and 8,075 living white pine seedlings (*55*, *73*).

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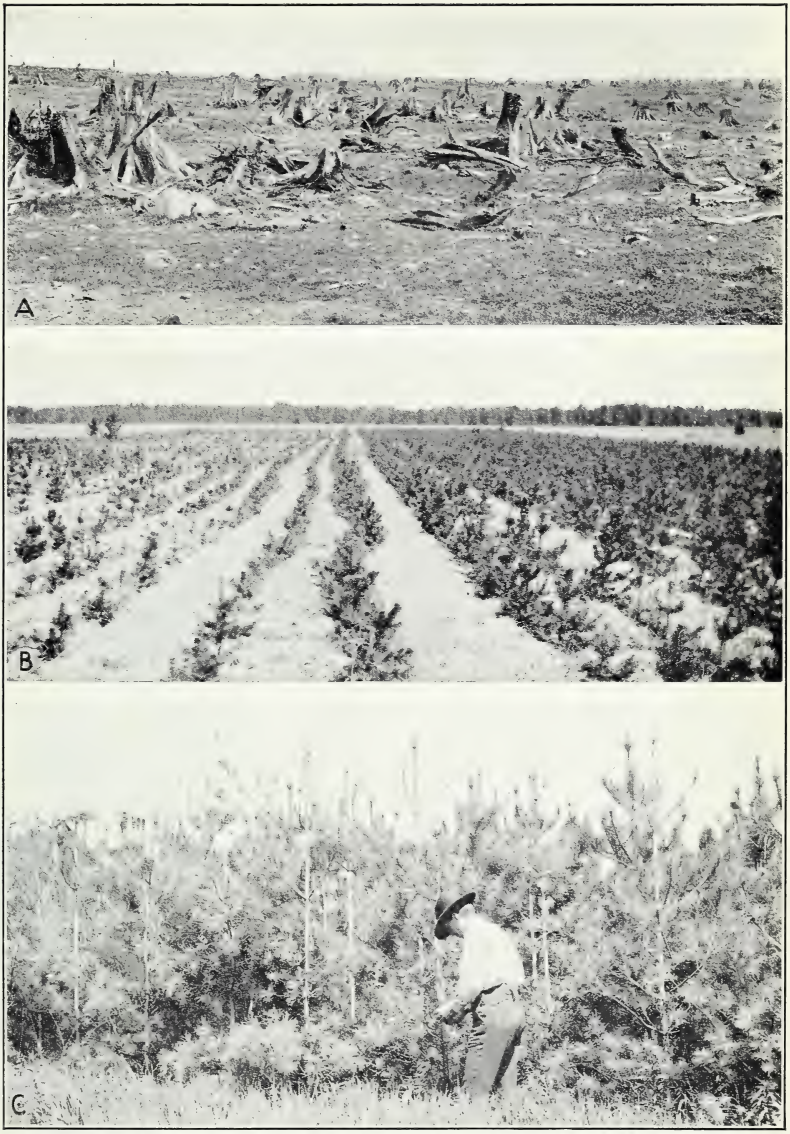
[4] The showing of white spruce is, however, probably not indicative for that species, for almost all of the white spruce planting has been done in Minnesota, where during the last few years the damage to small trees by snowshoe rabbits has been excessive. The white spruce plantations in Michigan and Wisconsin, where rabbit damage was not serious, have from 68 to 98 per cent of the trees living.



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THE REDEMPTION OF FOREST LAND IN THE LAKE STATES

A.—Land sadly in need of planting; the kind which makes forest planting a problem.
B.—Planted Norway pines growing splendidly on poor sandy soil which had been cultivated for farming and abandoned.
C.—Northern white pine eight years after planting on cultivated soil at Grand Rapids, Minn.

In southern Ontario, red oak acorns were sowed in the fall in furrows about 4 inches deep in a fine sandy soil and covered by dragging across the furrows. About 50 per cent came up. The trees were cultivated two years after sowing and averaged 5 feet high five seasons after planting. Seed-spot sowing of red oak has also been successful in Ohio (*60*).

Norway, northern white, and Scotch pine were sowed in seed spots by the Cloquet station (*41*) with moderate success. Best results were obtained in fall sowings under a stand of jack pine where the shade was found to be an advantage. On brushy, cut-over sites the smothering by leaves of the seedlings in the seed spots more than counteracted the benefits of the shade.

Although direct seeding may occasionally result in satisfactory establishment of seedlings, it is much more likely to fail. As a means of reforestation, its use is not recommended.

TYPICAL SITES FOR PLANTING

Differences in soil are chiefly responsible for the necessity of considering where to plant and what to plant in the northern Lake States. Variations within areas even as small as 20 to 40 acres may be so marked as to require a combination of two or more distinct planting plans. The natural tree and plant growth on the different soils are so closely related to the soil conditions that, when considered in connection with the original forest growth which was on the same area, they usually offer a more convenient means of describing and deciding on a planting plan than would a detailed examination of the soil.

In discussing planting sites, five different conditions will be distinguished:

1. The dry sandy lands with some tree growth of jack pine or scarlet or jack oak, and with little or no paper birch, pin cherry, or hazelnut (*Corylus rostrata* Ait. and *C. americana* Walt.). These lands were originally occupied by Norway pine or jack pine. They include the poor sites for Norway pine and the poor and medium sites for jack pine. Bare areas of blow sand, beach sand, and sand dunes are included in this group.
2. The sandy or sandy loam soils more retentive of moisture than those of the first group and having no jack pine, little or no scarlet or jack oak, but often paper birch or pin cherry. In distinction from the third class, they have no basswood, sugar maple, or raspberry (*Rubus idaeus* var. *aculeatissimus* [C. A. Mey] Regel and Tiling). Most of the cutover land which grew northern white pine or mixtures of northern white and Norway pine is in this class. It includes the good sites for jack pine, the medium and good sites for Norway pine, and the poor, medium, and some of the good sites for northern white pine and white spruce.
3. The loam or heavier soils with growth of basswood, sugar maple, or raspberry, and without sweet fern (*Comptonia asplenifolia* Banks) or blueberry (*Vaccinium pennsylvanicum* Lam.). The lands now or formerly occupied by sugar maple, eastern hemlock, basswood, yellow birch, or beech in different mixtures are in this class. It includes chiefly the good sites for northern white pine and white spruce.
4. Cultivated lands, whether they have been cultivated and abandoned years ago, or whether they are cleared and cultivated at the time of tree planting. The beneficial effect of clearing and cultivation of the ground on the planted trees is so marked in any and all soils that areas so treated must be considered as particularly favorable sites for planting. (Pl. 1, B.)
5. The swamps with wet muck or peat soils and forest growth of tamarack, northern white cedar, black ash, black spruce, or alder.

In addition to serving as a site indicator, the cover, composed of natural tree or other growth already on the area, directly affects the success of planting and must be considered in this light in the selection of a planting site. At one extreme are the cleared and cultivated lands which have already been considered separately. As natural tree growth increases, the plan for planting must be modified so that trees may be planted which are best adapted to meet the competition. Ordinarily, an area of which more than 40 per cent is occupied by natural tree growth requires a different plan from that for the same area with less than 40 per cent of tree cover. Where planting is done under a natural tree growth which occupies more than 40 per cent of an area, frequently called "underplanting," the trees should be planted in the openings wherever possible, and not close under the crowns of the larger trees.

CONSIDERATIONS IN SELECTING SPECIES TO PLANT

In selecting the kinds of trees to plant, there are five major considerations: (1) Their adaptability to the planting site; (2) the use for which the wood crop is desired; (3) the rate of growth; (4) the value of the wood products; and (5) their susceptibility to damage by insects, diseases, or other causes.

ADAPTABILITY TO PLANTING SITE

In choosing trees adapted to a planting site, as a general rule plant those kinds which are growing or have grown naturally, or have been planted successfully, on the same site. Largely on this basis certain species may be recommended for each of the sites distinguished previously. (Table 1.) For the jack pine-oak sandy soils, Norway pine and jack pine are the two species recommended. If bare sands are to be planted jack pine is the most promising species, reinforced if further movement of the sand seems likely by eastern cottonwood and willows (*33*, *56*). If there is more than 50 per cent cover of natural jack pine planting will usually be unnecessary and undesirable. If the cover is of oak, however, the planting of Norway pine and northern white pine is likely to give the best results.

TABLE 1.—*Kinds of trees to plant on different sites*

Site [1]	Species to plant according to the degree of natural tree growth on the area	
	Less than 40 per cent	More than 40 per cent
Jack pine–oak sands	Norway pine and jack pine	Norway pine and northern white pine.
Better sands or sandy loam soils without jack pine or raspberry; usually with paper birch or pin cherry.	Norway pine, northern white pine, white spruce, and red oak.	Northern white pine and white spruce.
Loam soils with sugar maple, basswood, or raspberry.	Norway pine, northern white pine, white spruce, white ash, green ash, and red oak.	

[1] Too little is known about swamp planting to make specific recommendations. The cleared and cultivated soils are not shown as a separate site in this table because the species to plant on them are the same as are recommended for the corresponding uncultivated sites with less than 40 per cent of natural tree growth.

On the moister sand and sandy-loam soils often naturally occupied by aspen, paper birch, pin cherry, or red oak, and also on the heavier soils where sugar maple, basswood, eastern hemlock, yellow birch, or beech have been cut and raspberries have come up after fires, Norway pine, northern white pine, and white spruce are the trees best adapted to the soils. On open sites where there is less than 40 per cent of natural tree growth, Norway pine is to be preferred. On the heavier soils or where there is more than 40 per cent natural tree cover, northern white pine or white spruce are likely to be more satisfactory.

The same suggestions for selection of species for planting apply to the cleared lands as to the soils with less than 40 per cent of tree cover. If the planting site has been cultivated recently however, or is cultivated at the time of planting, it is often possible to obtain good results with northern white pine as well as with Norway pine even on the dry sandy soils. (Pl. 1, C.) In general, however, northern white pine is more subject to damage by the extreme heating of the surface soil in exposed sites during the hot weather of midsummer.

Little swamp planting has been tried in the Lake States. Experimental plantings of red, white, Norway, and blue spruce were made in Minnesota by the Cloquet station (*41*). After two years, only 16 to 33 per cent of the trees of any of the species were alive. Since sufficient experience for guidance is lacking, planting in the swamps had best be guided by the general principle previously stated, namely, to plant those species which grow or have grown naturally on the site. For the Lake States swamps, this principle would indicate northern white cedar or possibly tamarack or black spruce or northern white pine as the trees to be tried. The trial should be on a small scale, however, since there is no certainty that any of them will be satisfactory.

A successful windbreak planting on peat soil which had been drained and cultivated in Beltrami County, Minn., is reported by S. S. Burton, formerly of the Cloquet Forest Experiment Station. The kinds of trees planted were American elm, Russian poplar, box elder, green ash, white spruce, and Scotch pine. With the exception of Scotch pine, more than 85 per cent of the trees were living two years after they were planted; the poplar, box elder, and ash were 3 to 3½ feet high. The hardwoods were planted as 2-year seedlings and the pine and spruce as 4-year transplants. The plantation was cultivated after planting as well as before. The results are suggestive but can not be accepted as reliable indications for planting on undrained swamps without cultivation.

The mine dumps in northern Michigan and Minnesota offer a special problem in forest planting which has yet to be attacked. Experience with planting under similar conditions in Pennsylvania (*19*) indicates that jack pine or Scotch pine will probably succeed and that they are the most promising species.

Suggestions as to the adaptability of different species to different planting sites have been limited to a few species. Those which are believed to be distinctly the best species for planting in the northern Lake States as a whole are Norway pine, northern white pine, white spruce, and jack pine. There may, however, be specific circumstances under which the planting of some other species would be more desirable.

UTILIZATION OF THE WOOD PRODUCT

One of the prime considerations influencing selection of species is the use for which the wood crop is desired. In the Lake States the largest present demands for timber are for pulpwood and for planing-mill products. Northern white and Norway pine have been and promise to continue to be thoroughly acceptable species for a multitude of uses in the form of lumber and planing-mill products. The two pines are used interchangeably for many purposes, including sashes, dimension stock, house construction, and doors, boxes, car construction, woodenware, and agricultural implements. A study of the wood-using industries in Minnesota in 1913 indicated 20 uses for Norway pine and 92 for northern white pine within the State. Norway pine, by reason of its greater strength and hardness, is slightly more suitable for construction purposes and for piling and ties. On the other hand, the soft and workable wood of white pine is particularly adapted to many specialized uses. Until recently these two species constituted one-third of the total consumption of wood products in the Lake States, and, although the demand for them is being absorbed by the western pines which are shipped east at high freight costs, it is safe to predict that northern white and Norway pine grown locally in the Lake States will always have a ready market.

Spruce is the most desirable species for the manufacture of paper pulp. About 540,000 cords of native spruce were used in 1925 in the Lake States for this purpose. An additional 750,000 cords of eastern hemlock and balsam fir are consumed annually, for which spruce would be substituted if it were available. Spruce is also a desirable wood for lumber, sashes and doors, boxes, woodenware, pails, fencing, and fuel. Small spruce trees bring good prices in December for Christmas trees (*16*). Twenty-eight uses of spruce were enumerated in Minnesota in 1913. The different kinds of spruce are quite similar in the properties of their wood. For any purpose white spruce is as good as any of the others.

Jack pine has come into use quite recently. Over 100,000 cords a year are now consumed in the Lake States for pulp, although only by those paper mills equipped to produce it by the sulphate process for craft paper. It is also being utilized for lumber, boxes, lath, car construction, woodenware, ties, and fuel; but although it is in good demand for these purposes, it is inferior to northern white and Norway pine for lumber products and to spruce for pulpwood.

Judged by usefulness and demand other species also deserve consideration for planting in the Lake States. These include white and green ash, which are in strong demand for handles, cooperage, vehicles, lumber, furniture, veneer, and many other uses. Red oak is always in demand for a multitude of products including ties, lumber, furniture, veneer, vehicles, and agricultural implements, as well as posts and fuel. The tamarack and European larch, which have similar wood properties, are or could be used for ties, pulp, lumber, car construction, paving, poles, cooperage, and posts. Northern white cedar has properties which make it specially suitable for ties, shingles, piling, poles, and posts, as well as lumber. Eastern cottonwood is chiefly used for pulp, fuel, lumber, veneer, boxes, woodenware, and vehicles.

RATE OF GROWTH

On the basis of their rates of growth on sites to which they are suited, the species may be arranged as follows, beginning with those that grow fastest: Eastern cottonwood, jack pine, European larch, Norway pine, northern white pine, white ash, basswood, red oak, white spruce, sugar maple, and northern white cedar. (Table 2.) The growth rate must, of course, be considered in connection with the length of time required for the tree to attain a usable size. In this respect, there is an advantage in growing species which are used in small sizes, as for pulpwood. For example, a crop of jack pine pulpwood can be grown in 35 or 40 years, whereas it will require from 50 to 80 years to grow saw timber of northern white or Norway pine. This question of the time required to grow the crop is an important matter and will be considered further in the discussion of returns from planting.

TABLE 2.—*Time required for planted trees to produce crops of merchantable timber for specified products*

Species	For posts, fuel, and pulpwood (6 to 8 inch trees)	For ties, poles, piling, and saw-logs (12 to 14 inch trees)	Species	For posts, fuel, and pulpwood (6 to 8 inch trees)	For ties, poles, piling, and saw-logs (12 to 14 inch trees)
	Years	*Years*		*Years*	*Years*
Eastern cottonwood	20–30	35– 50	Basswood	45– 60	80–100
Jack pine	25–45	60– 90	Red oak	50– 60	80–100
European larch	30–35	50– 60	White spruce	60– 80	100–140
Norway pine	40–50	60– 90	Sugar maple	70– 90	110–150
Northern white pine	40–50	60– 90	Northern white cedar	90–140	160–220
White ash	50–60	80–100			

VALUE OF PRODUCT

The money values of different species of timber differ widely. In 1925 in the Lake States, northern white and Norway pine were sold standing at $10 and $15 a thousand board feet. White spruce brought $2 to $5 a cord and jack pine $1 to $3 a cord for pulpwood. The comparative abundance of natural stands of jack pine in the region tends to keep its value low and makes jack pine a relatively less desirable species for planting. The hardwoods—including sugar maple and basswood, and often the red oak which grows with them—are sold for about $8 a thousand board feet. White ash has a somewhat higher value; eastern cottonwood is less valuable. Cedar commands good piece-rate prices for poles, ties, and posts.

SUSCEPTIBILITY TO DAMAGE

Norway pine stands out as a particularly desirable species for planting because it appears to be almost immune to insects and diseases. Northern white pine is often attacked by a weevil which kills the leading shoots and retards the growth in young trees. It is also subject to attack and destruction by the blister rust; but this need not discourage planting, for if the control measures worked out for this disease are taken promptly the risk of loss is small. White spruce is subject to losses due to the spruce budworm, especially in the natural stands where balsam fir is usually associated with the spruce; but in plantations where the spruce is planted pure or in mixture with pine, losses are not likely to be serious. Tamarack and European larch are both subject to attack by the larch sawfly. The danger of destruction by this pest is so great that for this reason alone planting of tamarack in the swamps can not be recommended. It may be that either species if planted on upland sites, where both make vigorous growth, would be able to resist successfully the attacks of the insect, although even this is not certain. Jack pine is attacked by several insects and a fungous disease, but so far none of these has proved to be serious. Other species, as sugar maple, basswood, red oak, white ash, eastern cottonwood, and northern white cedar, are not subject to damage to a degree that should affect their desirability for planting.

DOUBTFUL SPECIES

Several of the species that have been mentioned have certain obvious advantages but yet are not recommended for planting, either because too little is known as to their probable success in the northern Lake States or because existing plantations are not or do not promise to be satisfactory. These are Scotch pine, Norway spruce, eastern cottonwood, white and green ash, Russian poplar, and box elder.

Scotch pine has been extensively planted in the region. It adapts itself readily to a wide variety of soils including the poorest. The trees in the older plantings, however, are almost invariably so crooked and have such large, heavy limbs that it is doubtful whether they will be valuable for anything but cordwood. For that purpose Scotch pine is less desirable than jack pine, which grows faster and in addition to cordwood will produce lumber which is not excessively knotty. It is often stated that Scotch pine from seed produced in northern Russia (known as the Riga variety) or in the northern Scandinavian countries will grow straight and clean. If Scotch pine is to be planted, an attempt should be made to obtain seed or stock from these sources. It is probable also that the form of the trees could be improved by planting them not more than 3 or 4 feet apart. On the whole, however, Scotch pine can not now be recommended for planting in the northern Great Lakes region.

Norway spruce has also been planted in several parts of the region but has been only moderately successful. Usually only a few trees grow rapidly. It certainly has not done as well as, according to report, it has done in the southern part of the Lake States or in the Northeastern States, where its rapid growth and ease of propagation have sometimes given it the preference over the native spruces. The evidence from plantations in the northern lake States is not sufficient either to condemn Norway spruce or to prove that it is either inferior or superior to white spruce. Natural growth of white spruce does so well in the region, however, that it is recommended in preference to Norway spruce.

Cottonwood plantations were not found in the region studied, although many have been established in the prairie region to the west and south. Cottonwood planting and the yields from plantations in the Mississippi Valley and in Iowa have been discussed at length in published bulletins (*75*, *45*). The conclusions may be summarized briefly. The commercial growing of eastern cottonwood by planting deserves consideration as a means of supplying pulpwood, fuel, and farm timbers. It may be expected to yield 15,000 to 20,000 board feet at 40 years, or 20 cords in 20 years. Well-drained bottom lands, even if sandy, are the best planting sites. Upland or land covered with sod or a heavy growth of weeds should be plowed in preparation for planting, although plowing may not be necessary on open cut-over bottom lands where moisture is plentiful. Cuttings 10 to 18 inches long from fresh twigs may be planted at once or after being rooted in nursery beds. They should be set out in the spring, 7 to 10 feet apart each way. The rapid growth of eastern cottonwood makes good returns probable.

White and green ash, Russian poplar, and box elder have been planted on soils which were cultivated before and after planting. Under these conditions they have been thoroughly successful even in the severe climate of western Minnesota. It is not known whether they would be successful without cultivation. Russian poplar makes exceptionally rapid growth, but its timber value is uncertain and will probably not exceed that of eastern cottonwood. Box elder is not a desirable timber tree.

The ashes, however, are highly valued for many purposes. Green and white ash grow naturally in the region on good soils. The growing of different kinds of ash by planting and otherwise, chiefly in New York, Ohio, and Illinois, has been covered in a separate bulletin (*62*) from which the following suggestions are taken as being presumably applicable in the Lake States: Ash may be recommended for planting on cleared fields or good forest soils where it has grown naturally. One-year or two-year seedlings 6 inches to 2 feet high are most likely to succeed. They may be spaced 6 to 8 feet apart in mixture with northern white pine, sugar maple, or red oak. The site should be cultivated before planting and for one or two seasons after. On soils of medium quality, ash may be expected to yield 15,000 board feet to the acre at 60 years when the trees average 10 inches in diameter.

MIXED PLANTINGS

Plantings in the Lake States are still too young to indicate conclusively the advantages of specific mixtures of species. Since information from experiments or experience is lacking, it is necessary to limit the discussion of mixed plantings to some general principles and suggestions of possible mixtures which seem most likely to prove successful. In general, mixed plantings of more than one species are desirable because they provide more complete use of the productive capacity of the site and a larger product of higher quality and subject to more variety of use and market than plantings of only one species. If insects or disease attack the plantations and become epidemic, they are unlikely to damage seriously more than one kind of tree, and the damage to the more susceptible one is less than it would be if it were in a pure plantation. Even if one species be completely destroyed, the others remain to provide a timber crop on the area.

Theoretically it is desirable to plant a rapidly growing species with one of slower growth which will thrive in spite of the shade and competition of its associate. However, in plantations at Ottawa, Ontario, in which the slow-growing sugar maple was planted with European larch and Norway spruce, the maples were almost entirely eliminated before the conifers were 38 years old. Here the theory did not work out; and the outcome emphasizes the need for experiment.

Different kinds of trees have different capacities for obtaining from the soil the water and other materials that they need. For example, the roots of trees of two or more kinds planted in mixture make different demands upon different layers of the soil, and each is able to fill its needs more completely than if its neighbors were of its own kind, making similar demands upon the same layer of the soil.

As evidence of the more complete use of the soil and site by two kinds in mixture as compared with one, and as a practical reason for mixed plantings, European experience may be cited. This has shown that mixed stands of pine and spruce, pine and beech, and oak and beech produce higher yields, sometimes as much as one-third higher, than either kind by itself.

The hardwoods are desirable in mixtures because their presence decreases the risk of loss by fire, particularly by fires which might otherwise burn and spread through the crowns of the trees. The green foliage in summer and the bare branches in winter will not carry a fire. Actually, however, the application of this principle in the northern Lake States is limited; the dry sandy soils where the fire hazard is greatest are not suitable for the planting of hardwoods, and on the heavier soils a certain number of hardwoods are usually growing naturally, so that there is little need for planting.

Another reason for mixed plantings is that different kinds of trees are not equally beneficial in their effect in building up the fertility of the soil. As soil builders the hardwoods, such as oak, maple, and ash, are more effective than the pines and spruces. Some species may even be detrimental; in Germany, for instance, pure Norway spruce plantations have created soil conditions so unfavorable that the growth of the trees has been greatly reduced. This condition is avoided if other species, such as beech, are planted in mixture with the spruce.

Northern white pine occurs naturally in mixture with hardwoods on the heavier soils and undoubtedly produces the highest quality of timber under those conditions (*18*). The presence and maintenance of natural hardwoods in a plantation of white or Norway pine or white spruce is desirable as long as the hardwoods do not seriously interfere with the development of the planting conifers. If hardwoods are not present naturally, they may be planted in mixture with the pine or spruce.

With experience in mixed plantings lacking, however, there is little basis for recommendations or for predictions of success. In this, as in the selection of species for pure plantings, the best guide is probably the trees which grow naturally in mixed forests in the region. This principle would indicate either basswood, sugar maple, white ash, or red oak as kinds to be combined with northern white pine on good loamy soils. Northern white pine with white or Norway spruce may also be suggested. On the better sands and sandy loam soils a mixture of Norway and northern white pine may be recommended.

On the jack pine-scrub oak sandy lands of the northern Lake States on which only Norway pine or jack pine are suitable for planting, it is generally necessary to plant one of these two species pure. Norway pine is the more desirable, except for the production of pulpwood. In large operations with Norway pine, however, it would be advisable to break up the continuous plantings by introducing groups or strips of jack pine or even by leaving strips unplanted to serve as fire breaks. Where Norway and jack pine are planted alternately in the rows, the jack pine grows so much faster during the first 10 or 15 years that there is danger that it will seriously crowd and kill out the Norway pine. The oaks which grow naturally on these sites are probably desirable and should be saved to develop in mixture with the pines.

Mixed plantings may be arranged and carried out in several different ways. The different kinds of trees may be planted in alternate rows, or alternately in each row, or in two or more rows of one kind alternating with two or more of the other, or in groups of four or more trees of one kind to a group. Other arrangements by which two kinds are planted in different proportions are also possible, but too little is known for specific recommendation. Planting in alternate rows or strips requires only that half the planters have one kind and the other half the other kind of trees, and that they are started right at the beginning of each row so as to give the desired alternate or strip arrangement of the two kinds. Alternating the kinds in each row is usually done by having two planters work the same row. One goes ahead and plants his trees 10, 12, or 16 feet apart, and the other follows him, putting in the other trees midway. These schemes do not greatly increase the cost over that of planting a single kind. Group planting requires more care and increases the cost.

Alternate rows or alternate trees in the row give the most intimate mixture and result in the most severe competition, so that if one species lags behind it is likely to be seriously suppressed or killed. This danger is partly avoided and at the same time many of the advantages of mixed planting are obtained by planting three or more rows of one kind, alternated with three or more of the other. Until more is known about the development of mixed plantings this plan is safest.

Another method of planting mixtures is to plant first the slower growing kind or the one to which it is desired to give a start, and a few years later to fill in with the other species. This plan would be applicable to mixed planting of Norway and jack pine in which the Norway pine needs a start of three to five years to hold its own, but it would almost double the cost of the planting because it would necessitate covering the same area twice. The later planting of a more rapidly growing tree has practical importance, however, in replanting the fail places in a plantation in which many of the trees have died. Replanting with some other sutiable kind of tree of faster growth than that originally planted serves not only to fill up the holes but also to secure the benefits of a mixed planting.

SEASON TO PLANT

Forest planting may be done either in spring or fall. Large areas have been planted in the Lake States in both seasons with excellent results. The degree of success obtained depends more upon the weather of the individual season than it does on any general difference between spring and fall. For example, spring plantations established when soil moisture and the weather following planting are favorable will do better than plantings made in a dry fall, and plantations established during a rainy fall will do better than those set out in a dry spring. Similarly, there are marked differences in the success of planting in succeeding weeks of the same season.

The safest and most general rule, especially for the private landowner, is to plant the trees as soon after the frost goes out in the spring as the ground can be worked and before the buds have opened and new growth is started. It is therefore desirable to obtain the trees from a nursery as near the planting site as possible. Trees for spring planting should be ordered in the winter and for fall planting not later than the preceding spring. The beginning of the spring-planting season will be between April 1 and 10 in lower Michigan, and about April 15 in the northern part of the region. With favorable weather, planting may be continued until early in June, although the later plantings are likely to prove less successful than the earlier ones.

Planting should not be undertaken, if it can be avoided, following more than a week of dry weather. It is better to heel in the trees where they can be watered and wait until rain comes before continuing, although on large jobs where many men are employed such a plan may not be feasible.

Fall planting may begin with the first good rains in September and continue through October. Hardwoods should not be moved and planted in the fall until they have dropped their leaves. Species like European larch which start their growth very early in the spring are more likely to succeed when planted in the fall. As in the spring, fall drought periods should be avoided for planting. In general, the fall is likely to be a little drier than the spring. On heavy, clayey soils, subject to heaving, there is danger that small seedling stock may be heaved out during the winter. On the other hand, trees are entering a dormant period in the fall and are somewhat less susceptible to damage from the drying than they are in the spring. They are, moreover, not immediately exposed to the extreme heat which usually follows within a month or two after spring planting. Finally, other work in forested and agricultural regions is not so urgent in the fall and labor for planting is easier to obtain. On the national forests of the Lake States the advantages of fall planting are considered to outweigh those of spring so certainly that almost all planting is now done in the fall.

Spring planting can be begun several days earlier than otherwise and often before plowing is possible if furrows have been plowed the previous fall, because furrows thaw out before the adjacent sod. In the fall, planting in furrows previously plowed may begin immediately after the first good rain; although it would often be impossible to plow at that time because the soil below the surface would still be too dry. Plowing the furrows well in advance of planting, therefore, increases the length of the planting season both in spring and fall.

It is also possible in favorable seasons, to plant trees during the summer. Watson (*74*) describes the results of an experiment on the Higgins Lake State Forest in Michigan in which the northern white pine was underplanted each week from June to September, inclusive. Counts made later showed that the trees planted in July and August did as well as those planted in June, or better, and that 80 per cent of them were living.

On the other hand, in an experiment in 1925 and 1926, in which 2-year seedlings of Norway pine were, with two exceptions, planted each month from April to November, inclusive, on an open sandy site of the Huron National Forest, the following percentages of trees were living in the fall of 1926:

Month planted	1925 planting	1926 planting	Month planted	1925 planting	1926 planting
April	91	74	August	60	100
May	94	66	September	74	100
June	66	65	October	----------	100
July	27	77	November	46	----------

The season of 1925 was distinctly unfavorable, and the late spring and early summer of 1926 were even worse. Repetition of the experiment in 1927 may yield better results. The figures illustrate the marked differences in survival from one year to the next resulting from the variations in weather during the planting season. On the whole, summer planting is less likely to be successful than either spring or fall planting.

SIZE AND AGE OF TREES FOR PLANTING

For Norway pine, 2–0 seedling[5] or 2–1 transplant stock is recommended, the latter for private planting on a small scale or for brushy sites. For northern white pine 2–1 transplants or 3–0 seedlings are suggested, and for white spruce, 2–1 or 2–2 transplants. For jack pine and white ash, 1-year seedlings, and for cottonwood, 1-year rooted cuttings are almost always the most satisfactory. (Table 3.)

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[5] The trees available for planting from nurseries may be from 1 to 5 years old or older. Usually they are grown in the seed beds for 1, 2, or 3 years, and then, if not used at once for field planting, are transplanted in the nursery and allowed to grow 1 or 2 years longer before being set out. This transplanting makes sturdier trees, with compact, bushy root systems, more desirable for planting. Forest nursery stock is known and will be referred to in this bulletin by a numerical system, the first figure representing number of years in the seed beds and the second number of years transplanted. Thus, 2-year-old seedlings are called 2–0 stock, and 1-year seedlings transplanted at the end of the first year and grown 2 years in the transplant beds are known as 1–2 stock.

TABLE 3.—*Age class of nursery stock for planting under light and heavy competition of sod, brush, or tree*

Species	Under light competition [1]	Under heavy competition	Species	Under light competition [1]	Under heavy competition
Norway pine	2–0 2–1	2–1 2–2	Red oak	1–0	1–0 2–0
Northern white pine	3–0 2–1	2–1 2–2	Tamarack or European larch	2–0	2–0
White spruce	2–1 2–2	2–2 2–1	Eastern cottonwood (rooted cuttings)	1–0	1–0
Jack pine	1–0	1–0 1–1	Basswood	1–0	1–0
Norway spruce	2–1 2–2	2–2 2–1	Sugar maple	2–0	2–0
White ash	1–0	1–0			

[1] Classes in this column are also suitable for sites with little or no competition.

The 1, 2, 3, or 4 year old nursery stock generally used and recommended for forest planting is small and does not make a showing for several years after it is planted. One-year jack pine seedlings are 3 to 5 inches high. Two-year seedlings of northern white and Norway pine are usually 2 to 5 inches high and have roots 6 to 12 inches long. The 3-year and 4-year transplants may be 4 to 7 inches high with root systems which are more bushy but not much longer than those of the seedlings.

Although forest-planting stock of any species is small, trees of these sizes have been found to be most satisfactory for several reasons: (1) They adapt themselves to the new conditions of the planting site more easily and are more likely to succeed than larger stock; (2) they are cheaper to raise or to buy; and (3) they can be planted more quickly and more cheaply and with good success by unskilled labor. Finally, they may be expected to return a larger profit on the investment when mature than can be predicted for the larger transplant stock, of which the slightly better growth and survival do not compensate for the increased costs carried at interest over a long period.

These economic considerations are usually of first importance, and they must always be weighed with comparative growth and survival in selecting a particular size and age of nursery stock among the two or three which may be expected to live and grow satisfactorily under any given conditions. The condensed recommendations just made and those in Table 3 are based upon a combination of economic with other considerations. Costs of stock and of planting are taken up in detail in a later section of the bulletin. The following paragraphs and Figure 2 refer only to the results in growth and survival.

The plantations of Norway and northern white pine in which 2–2 stock was used have been most successful. (Fig. 2). Three-year transplants (2–1) of the white pine were only a little less successful than the 4-year (2–2), and those of Norway pine were no better than the 2-year or 3-year seedlings. The 3–0 white pine does not make a favorable showing in Figure 2, and the recommendation for its use is based partly on its low cost as compared with transplant stock and partly on the reported success which has been attained with it in younger plantations than those studied.

More detailed study of these general differences in the classes of planting stock, indicate that they are not large, that they have frequent exceptions, and that they are likely to be obscured or even reversed in individual plantings by the action of other facts which are more important. In height growth, for example, the Norway pine plantations on the open, sandy soils show almost the same average height growth for 2–0, 1–1, 3–0, and 2–1 stock. The 2–2 stock averages only 1 to 2 feet higher 10 years after planting. If 2–0 seedlings had been set out two years earlier, they would probably be as tall as the 2–2 stock is now. On the contrary, the height growth of 2–0 northern white pine underplanted is distinctly better than that of 3–0, 4–0, or 2–2 stock. Measurements of heights of different classes of stock of Norway pine on the Michigan National Forest five years after planting, showed 15 inches for 1–0 seedlings, 20 inches for 2–0, 21 inches for 1–1 transplants, and 27 inches for 2–1. These differences in height, however, will undoubtedly become insignificant long before the trees are mature.

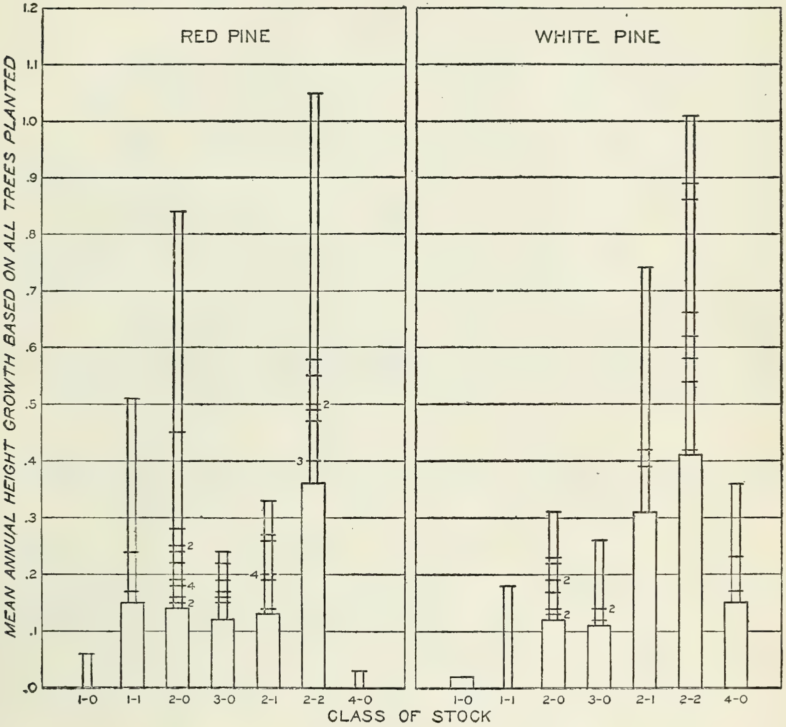


FIGURE 2.—Relative success of different classes of nursery stock. Wide bar marks average of all plots; single plots that attain more than the average are notched on narrow bar, numerals indicating two or more plots of the same height

The effect of the class of planting stock on the percentage of trees which live is more significant than its influence on growth. Plantations of 2–2 Norway pine on the open sandy soils have from 60 to 75 per cent of the trees living on the average, as compared with 50 per cent in the 2–0 plantings. The corresponding averages for northern white pine underplantings are 54 per cent and 46 per cent. The Norway pine plantations of 1–1, 3–0, and 2–1 stock on the jack pine-oak stands have 70 per cent to 80 per cent of the trees living, or more than either the 2–0 or 2–2 plantings, in contrast to the Norway pine on better sandy soils, where the average percentages for these three classes are only 35, 45, and 46 per cent, respectively.

Where white spruce was planted on the Chippewa National Forest, 2–1 stock which had been in the field one to five years had 50 to 88 per cent of the trees living. Thirteen acres planted with 3–0 seedlings had 93 per cent living at the end of the second year. One plantation of 2–0 seedlings had 69 per cent survival after five years, and another younger one, 90 per cent.

In experiments with planting stock of different classes at the Cloquet station (*41*) 2–2 stock of northern white and Norway pine had higher percentages of the trees alive than other classes. (Table 4.) The growth of the 2–2 stock was also greatest, and the superiority in both growth and survival was maintained for the first 10 years after planting. This transplant stock (2–2) of northern white and Norway pine gave better results when planted (1) under stands of jack pine of different sizes and densities, (2) on cut-over barren sites, (3) where sweet fern formed the predominating cover, and (4) in the thick brush. In another series of experiments (*29*), observed five years after planting, the survival of transplants was slightly better than that of seedlings and the growth markedly greater.

The results of experimental and large scale plantings summarized in Table 4 indicate that the transplant stock, and especially the 2–2 stock, has larger percentages of trees living but that the differences are small.

TABLE 4.—*Survival of different classes of Norway and northern white pine stock, on various plantations, in percentage*[1] *of living trees*

Classes of stock	Norway pine					Northern white pine	
	Michigan	Minnesota	Minnesota	Minnesota[2]	Cloquet	Minnesota[2]	Cloquet
1—0	70						
2—0	85	52	42	48	63	66	71
1—1	89						
3—0		48	36	40	73	69	68
2—1	99	60	37	50	62	75	81
1—2							75
2—2					87		83

[1] Plantings were made on the Michigan and Minnesota National Forests and at the Cloquet (Minn.) Forest Experiment Station on small experimental areas, except as noted. The classes for which no percentage appears were not included. Survival counts were made three to five years after planting.

[2] Plantations of 130 to 400 acres.

Usually the transplant stock of Norway or northern white pine shows a slight superiority in growth and survival. The differences in these two respects, however, are not sufficient to cause a plantation of 2–0 or 3–0 seedling stock to fail where one of 2–1 or 2–2 transplants would succeed. The small advantages in increased growth and survival are counterbalanced by the greater cost of raising or purchasing and planting the transplant stock. As a result of experience on the Michigan and Minnesota National Forests, the

Forest Service has concluded that for Norway pine in these localities first-class 2–0 seedlings with good roots are superior to transplants in terms of final cost of the established plantation. This conclusion may be made general for the region. Similarly, the economic considerations indicate that 3–0 or 2–1 stock of northern white pine and 2–1 stock of white spruce are to be preferred to the more costly 2–2 stock.

Successful plantations of Norway and northern white pine have been established by digging natural seedlings and resetting them on the planting site. (Pl. 2, A.) Experiments with wild stock at the Cloquet station gave reasonably good results, although not as good as with nursery stock. Ordinarily the wild seedlings are not easy to find in large quantities. Moreover, they have a poorer root system and are less likely to succeed than those grown in nurseries. Unless they can be dug in spare time or without incurring special cost for labor, they are usually more expensive than stock purchased from the State nurseries. If wild seedlings are used, they should not be over 8 inches high; larger ones are less likely to survive the transplanting.

The following conclusions in regard to age of trees for planting may be drawn:

Good stock of 1–0 jack pine, 2–0 Norway pine, 3–0 northern white pine, 2–1 white spruce, the smallest sizes which are likely to succeed, are better than larger and more expensive stock when judged by the final cost of established plantations. The differences between these different classes of stock as measured by growth or survival are small and unimportant as compared with their relative cost.

For the hardwoods, 1–0 seedlings are satisfactory.

Digging wild seedlings is usually a less successful and more expensive method than purchasing small nursery stock for planting.

METHODS OF PLANTING STOCK

Different hole, silt, and furrow methods and combinations of them have been tried in an effort to establish plantations at a minimum cost without sacrificing survival or favorable development of the trees. All of them have given satisfactory results when practiced by reasonably competent crews under good supervision.

HOLE METHOD

In the square or deep hole method a mattock or spade may be used in planting. A hole is dug sufficiently large and deep to allow the roots to be extended to their full depth. The tree is held perpendicularly in the hole with roots fully extended, while the better soil removed from the hole and separated from the stones, grass, and roots is packed firmly about the roots. The hole is filled and well packed except for a top layer left loose to serve as a mulch. Ordinarily, one man makes the holes, and another plants the trees. On slopes, care should be taken to see that the tree is upright and that the surface of the soil placed around the tree is at the same angle as the slope. If depressions are left, washing occurs, or the hole is filled with leaves and litter which may smother the plant. When the hole method is used on areas covered with heavy sod, it is desirable to remove the sod before the hole is dug and, after the tree is planted, to fill the hole with soil. The hole method is adapted to all species and sites, since the mattock and grub hoe can be used on both rocky situations and sandy areas, while the spade works effectively in sand or sod.

HOLE METHOD IN FURROWS

Furrows may also be used effectively in combination with the hole method, the trees being planted in mattock or spade holes in the bottoms of the furrows. In heavy sod, ploughed furrows make it unnecessary to spend time removing sections of sod with the mattock or spade.

DIRECT FURROW PLANTING

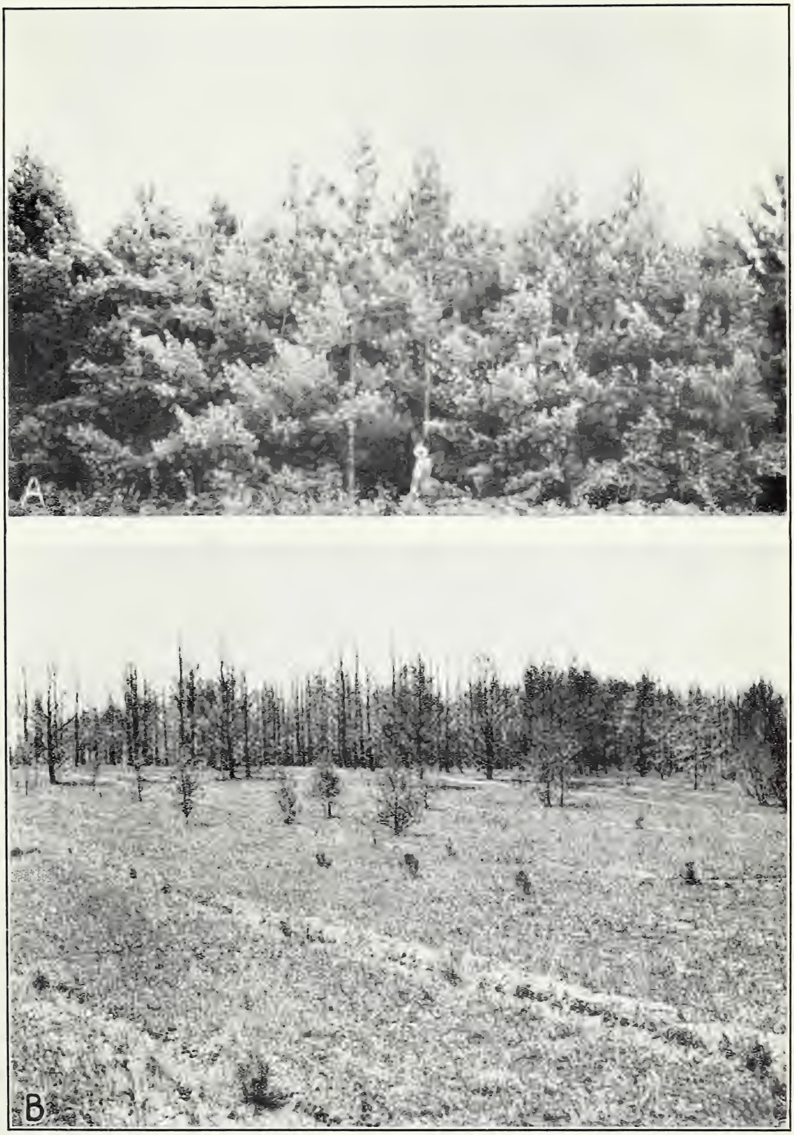
Recently a method has been suggested (*28*) by which the trees are planted directly in plowed furrows. This has been as successful as the mattock-hole method in New Jersey on abandoned fields. The roots are spread out in the bottom while the stem is held against the side of the furrow. Loose soil is then pulled over the roots and firmed with hand or foot and a layer of loose soil added on top. This method should be quick, cheap, and easily practiced by unskilled labor.

SLIT METHOD

In the slit method, a planting bar, spade, or mattock is used. The planting bar consists of a steel wedge 8 to 12 inches long, 3 to 4 inches wide, and three-eighths of an inch thick at the top, on a galvanized-iron bar with or without a grip handle and a step attachment. The bar is driven vertically into the soil with a single stroke to the depth required, pushed forward to an angle of 45°, slipped slightly downward to take a new hold at the bottom of the hole, and finally brought back to a nearly perpendicular position. This forms a rectangular slit into which the roots of the plant are lowered. The roots are shaken out and the slit is closed by another thrust of the bar behind the plant. The planter then closes this last hole—to prevent excessive drying of the ground near the roots—by a thrust of his heel as he steps forward.

The details of this method have been studied and developed on the Huron National Forest to a high degree of excellence, which is attested by the effectiveness and low cost of the planting. The method has been criticized because all the roots are placed in one plane, but investigation has shown that the roots grow evenly in all directions in the sand soon after planting. It is better adapted to loose than to heavy, sticky soils. It is also better suited to small stock than to large stock with bushy roots.

When a spade is used, experience on the Chippewa National Forest shows that the best results are obtained by pulling the spade toward one when it is first driven into the ground, then driving it a little further into the ground and pushing it away. The tree is then placed in the corner of the hole between the two solid walls, and the dirt is well packed about the roots. The method can be used advantageously in underplanting. It is not well adapted to a planting area which is heavily covered with sod, because the newly set trees



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A.—Twenty-year-old plantation of Norway and northern white pine in central Wisconsin established by digging wild seedlings
B.—Plowed furrows with recently planted Norway pines, on burned-over jack pine land in Michigan

suffer in competition with the surrounding vegetation. This method, wherein each man plants his own trees and preparation of the ground is unnecessary, is more rapid than the square-hole method.

SLIT METHOD IN FURROWS

The slit method in furrows is the most economical method for planting on any land where furrows can be plowed (*36*). Furrows 12 to 14 inches wide are plowed at regular intervals to a depth of 2 to 3 inches. (Pl. 2, B.) A sulky or breaking plow has been used successfully. The trees are planted in the furrows by the slit method. The advantages of the method are that it is rapid, it eliminates the competition of surrounding vegetation for a period of two to three years or longer, and the furrows serve to check or control the spread of any fire that might occur.

COMPARISON OF RESULTS BY DIFFERENT METHODS

Experiments (*50*) with 2–2 northern white pine transplants in New York gave, two years after planting, the following results:

Method	Soil	Percentage living
Furrow hole	Clay loam	90
Hole	do	87
Mattock slit:		
Sod removed	do	86
Sod left	do	62
Hole	Silt loam	78
Furrow hole	do	98

A similar experiment (*12*) in Massachusetts with 2–1 northern white pine and Norway spruce gave the following results in percentage of trees living after two years:

Method	Percentage of northern white pine	Percentage of Norway spruce
Mattock hole	92	78
Slit, sod off	80	66
Slit, sod on	63	41

The removal of a square of sod as a part of the hole or slit method increases the success of the planting, especially on areas of heavy sod or brush. Wherever the brush or timber is not so thick as to prevent, the plowing of shallow furrows in which the trees can be planted gives better results than similar planting without the furrows. For example, on a low sandy soil with 40 per cent of laurel (*Kalmia angustifolia* L.) cover, jack pine and northern white pine planted in furrows had 58 per cent and 69 per cent, respectively, of the trees living, whereas the adjacent area where furrows were not plowed had only 34 and 39 per cent. Also, the growth in the plowed plantation was distinctly better. This example also suggests that the benefits of furrow planting are greatest where the brush competition is heavy and plowing most difficult. Another comparison may be made of two well-established plantations on an upland sandy soil, alike in all respects except that the trees in one were planted in slits in furrows and in the other by the slit method without furrows. Of those planted in furrows 74 per cent of the jack pine and 72 per cent of the Norway pine survived, whereas of those from the unfurrowed planting only 21 per cent of each of the species remained alive.

On the better, sandy sites, underplanted northern white pine had an average annual height growth of 0.23 foot by the slit method and 0.42 foot by the hole method. On the other hand, the percentage of living trees was 58 by the slit method and 39 by the hole method, a poor showing which was probably due in part to other causes. Norway pine on the sandy soils grew at an average rate of 0.2 foot when planted by the slit method, 0.27 foot by the slit-furrow method, and 0.32 foot by the hole method. The percentages of living trees by the three methods were 40, 58, and 60, respectively. The advantages of the hole and furrow methods in increased growth and survival although real are small. (Fig. 3.) In more recent plantations, efficiently planted by any of these methods with the technic developed from earlier experience, 80 per cent or more of the planted trees have lived.

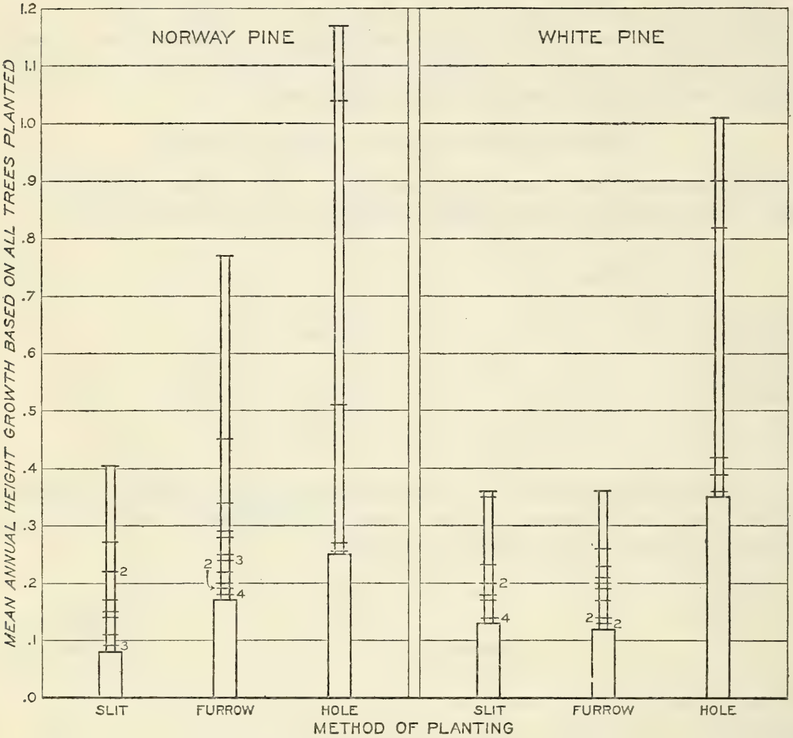


FIGURE 3.—Relative success of plantations by different methods of planting. Wide bar marks average of all plots; single plots that attain more than the average are notched on narrow bar, numerals indicating two or more plots of the same height

The growth and survival of the trees should be weighed with the costs in the choice of a planting method. Slit planting is the least expensive. The cost of plowing furrows adds little to the expense because it is largely compensated by the reduction in time of actual planting. The hole methods are slower and more expensive and are only justified on extremely brushy or rocky sites. Costs are discussed in more detail in a later section. However, considering them in general terms along with growth and survival, the conclusions in regard to methods of planting may be summarized as follows:

Slit planting with a planting bar or spade is the quickest and cheapest method of setting the trees and results in satisfactory growth and survival. However, all of the methods have usually been successful, and the differences between them in survival and growth are small. The greater costs of the more expensive methods are not justified by any prospect of more than partial compensation in the form of more rapid growth, greater survival, higher yields, or higher quality of product.

The trees should be planted in furrows wherever plowing is possible.

SPACING OR NUMBER OF PLANTS TO THE ACRE

The number of trees that are planted on an acre, or the distance between trees, is important because it affects the cost and returns of planting and the amount and quality of timber that will be obtained from the plantation. Usually the trees are planted in parallel rows and spaced equally in the rows, each four trees forming a square. Actually, however, it makes no difference whether the trees in a row are exactly in line with those in adjacent rows. Similarly, for furrow planting the rows need not and can not be exactly straight or parallel. Triangular spacing, requiring more trees to the acre for the same spacing is also satisfactory, but it is less easy to organize the work and planting crew for this than for the rectangular system.

Plantings have been made with spacing between the trees varying from 3 by 3 feet to 10 by 10 feet. The smallest spacing, which requires 4,840 trees to an acre, is too close for the best results, and the largest, which requires only 435 trees to the acre, is too wide. A large proportion of the plantations on the national forests have been made with 700 to 800 trees to the acre, which is the equivalent of a spacing of about 7 by 8 feet. These numbers are supplemented usually by 100 to 200 trees to the acre of natural jack pine and oak which are found on most of the planting sites. The Wisconsin and Minnesota State Forest Services in their recommendations to private owners have usually suggested 6 by 6 foot spacing, or 1,210 trees to the acre. On the State forests in Michigan closer spacing has been used, varying from 3 by 3 or 4 by 4 feet in some of the earliest plantings to an average of 1,500 or 1,700 trees to the acre spaced 5 by 6 or 5 by 5 feet over large areas in the bulk of the State planting.

For Norway, northern white, and jack pine, and white spruce, 5 by 5 to 8 by 8 spacing should be used. Six by six feet or 1,210 trees to the acre can be recommended. At this rate the branches of the trees come together when they are from 10 to 20 years old. The lower branches of the pines begin to die from shading between the ages of 15 and 25 years, when they are not more than 0.75 inch in diameter and average only about 0.5 inch. By the time the trees are 25 years old, the branches will be dead 10 to 15 feet from the ground. At 25 to 30 years, when the trees are 4 to 5 inches in diameter, some thinning will be necessary.

With 5 by 5 spacing the crowns of the trees completely shade the ground two or three years earlier, the lower limbs begin to die sooner and when they are slightly smaller in size. Some of the trees should be removed about 15 years after planting. The value of the products from thinning these smaller trees will be less, but the quality and value of the timber finally cut from the area will be higher. On the other hand, with wide spacing of 8 by 8 feet or 680 trees to the acre, the cost of planting will be easily one-third less than if 6 by 6 spacing is used, the limbs will be larger, the lumber more knotty and its value lower, and no product or return from thinnings will be obtained until the trees are 40 or 50 years old. Tarbox (*64*) has shown for northern white pine in New England that as the number of trees per acre up to 20 or 30 years old is increased the size of the knots is decreased, and hence the quality of the lumber is improved. Similarly, from observations of Norway pine in New England Reed (*53*) has concluded that 4 by 4 foot spacing is the most desirable for the production of high-quality timber.

The effect of spacing on the cost of planting and the future ability of the timber to earn a certain percentage interest on the investment may be illustrated by an example. Assuming all other conditions the same, the approximate cost of establishing Norway pine plantations, as explained later under costs, is $4.50 for 680 trees to the acre spaced 8 by 8 feet, $7.50 for 1,210 trees spaced 6 by 6, and $10.50 for 1,740 trees spaced 5 by 5. If these costs, together with other expenses, are carried at 5 per cent compound interest for the 60 years until the trees become merchantable, the timber will have to have stumpage values per thousand board feet of about $11.50 for the 8 by 8 planting, $15.50 for the 6 by 6, and $19 for the 5 by 5. The plantations in the Lake States are not yet sufficiently old to give information as to the relative advantages of different densities of planting, but it does not seem likely that the possible profits from thinnings, or the higher quality and value of the timber from a plantation spaced 5 by 5 feet or closer, will more than offset the additional cost of planting 1,740 or more instead of 1,210 or less trees to the acre. Moreover, it is quite likely that the yield in board feet at 60 years of the 8 by 8 foot planting might be greater than for the closer spacings.

The probable percentage of trees which will live is another important consideration in determining the proper spacing of a plantation. The average for the older plantations in the region has been given as 56 per cent for Norway pine and jack pine, and 57 per cent for northern white pine; 85 per cent is the average for the recent large plantings in Michigan. It is desirable to have more than 600 established trees to the acre during the early life of a plantation. To secure this number will require the planting of not less than 800 trees to the acre where 85 per cent survival may be expected and not less than 1,200 if only 50 per cent of them are likely to live. If allowance is made for possible heavy losses in unfavorable years, through drought or other cause, still larger numbers of trees per acre may be planted. Such heavy losses are exceptional, however, and if they occur, they may be remedied by replanting the openings where trees have died. Replanting is not necessary if more than 600 trees to the acre are living, and even when the number is reduced to 300 or 400 a reasonably good crop of timber may be obtained without replanting, provided the trees remaining after the early losses are not so unevenly distributed as to leave large openings.

If considerable numbers of seedlings or trees of desirable kinds are already established on the planting area, the number to be planted may be reduced correspondingly. Similarly, in underplanting, the trees should be planted in the openings or where there are spaces of over 15 feet between the natural stems, with little regard for the number of trees planted on each acre or for any geometrical scheme of spacing or arrangement in rows. The operation should be planned, however, so that a full stand will be obtained, even if not more than 200 or 300 trees to the acre are set out.

There are several other considerations in deciding upon the spacing to be used. The presence and size of knots and limbs, already noted as an effect of spacing, make it needful that the spacing should be closer if the aim is to produce high-quality saw timber over a long period of years. If there is a local market for small trees for pulpwood or fuel the planting should be closer, since higher yields will be obtained from the greater numbers of trees which will be cut when small, and there may also be a profit in the product from early thinnings. Spruce may often be planted advantageously as close as 4 by 4 feet, or 2,722 trees to the acre, because a part of the trees can usually be cut and sold at a good profit for Christmas trees when they are between 5 and 10 years old (*16*). It is generally stated that trees such as jack pine, Norway pine, and eastern cottonwood, which develop best with ample overhead light, may be planted farther apart than the more shade-enduring kinds such as spruce and northern white pine. Eastern cottonwood, for example, has done well when planted as widely as 8 by 8 or 10 by 10 feet. If there is much brush or other vegetation on the area, closer planting will crowd it out sooner, and this is desirable for the best growth of the trees. Finally, planting on poor soils should be closer than on better soils, to offset the heavier losses which are likely to occur on severe sites.

An interesting series of plantations at Ottawa, Ontario, set out in 1887 (*46*), in which the same kinds of trees were planted in adjacent plots with 5 by 5 and 10 by 10 foot spacing, illustrates the greater diameter growth in inches of the widely spaced as compared with the closely spaced trees. Measurements made in 1925 are as follows:

Species planted	Diameters, 5 by 5 foot spacing	Diameters, 10 by 10 foot spacing	Species planted	Diameters, 5 by 5 foot spacing	Diameters, 10 by 10 foot spacing
	Inches	*Inches*		*Inches*	*Inches*
Norway spruce	5.5	9.5	Paper birch	5.5	7
Northern white pine	6	9	White ash	4	5
European larch	5	8	American elm	4	7
White spruce	5	6.5	Sugar maple	3.5	6

The differences in diameter are compensated by the differences in numbers of trees per unit area, however, so that the volumes of the stands of these two spacings would be closely similar at this age. For example, whereas of the white pine there might be left on an acre 400 of the 435 trees originally planted 10 by 10 feet, 800 out of 1,740 might be left from a 5 by 5 foot spacing. There was no appreciable difference in height between the two plantations. The 400 larger trees would have nearly the same volume per acre as the 800 smaller ones. The wider-spaced plantation would be ready for cutting for lumber sooner, but the other would provide an immediate small yield in thinnings and a later cut of better-quality lumber, so that no positive economic advantage can be shown either way. It is likely, however, that plantings 6 or 7 feet apart might give better results than either the 5 by 5 or 10 by 10 foot spacing.

This is an example of the close interrelation between number of trees planted per acre, diameter growth of the individual trees, volume of wood production per acre, and profitableness of planting. When older plantations become available for study and experiment, it will be possible to say how these factors can be controlled and the maximum profits realized by using the best spacing in planting and the right time for thinnings.

CULTIVATION

Cultivation of the soil either before or after planting is not necessary in the region under discussion for the establishment of successful plantations of pine or spruce, although probably necessary for hardwoods and for all kinds of trees in the prairie region of extreme western Minnesota. However, cultivation of a plantation stimulates the early growth of the trees and assures the survival of a larger percentage of them, as it does in any crop. In an experimental planting of Norway spruce, Chittenden (*17*) found that the cultivated trees grew 2.9 feet and the uncultivated 1.8 feet in height during the four years after planting. The advantage to forest trees, however, probably lasts only during the early life of the trees, and it is questionable whether the increased growth will offset the cost of cultivation.

TOOLS FOR PLANTING

Different forms of spades, mattocks, grub hoes, and planting irons or bars have been tried and developed for planting work. Six different tools or methods were used in experimental plantings of northern white and Norway pine at the Cloquet station (*41*). These in the order of cost were heart spade (at $2.10 per 1,000 trees), wedge spade, mattock side hole, cylindrical spade, iron wedge, and mattock center hole (at $4.64). All of these but mattock side hole gave over 60 per cent survival after two years, except in thick brush, where heavy mortality resulted regardless of the method.

HEELING IN

If the trees can not be planted for several days after they are received, they should be heeled in at or near the planting site. This is done by digging a trench with one side at an angle of 45° and deep enough to hold the roots. The bundles in which the trees are packed are cut, and the trees are spread in a layer not over 2 inches thick along the sloping wall of the trench. They are then covered with earth up to the tops and kept shaded. Watering should be heavy and frequent. Trees can be removed from the trench as they are needed for planting.

PLANNING THE PLANTING OPERATION

The planting operation should be planned in advance, taking into consideration the area to be planted, the number of trees which will be planted per man per day, and the number of men required to do the job in the time available in one or more planting seasons. The camp or camps, if needed, should be carefully located as near the planting site as may be, and at the same time accessible to a road or trail by which equipment and stock may be brought in. Ordinarily there should not be more than 10 or 15 men in a crew under a single foreman, or if a larger crew is employed it should be divided into units of this size; each under a boss. Thorough instruction and constant supervision of the planters by the foreman is essential for successful planting.

Local men, farmers, and settlers in the vicinity usually make the best planters. They are likely to be available in successive years, and their accumulated experience will make their help increasingly valuable. They take more interest in the work at the time and more interest in the plantations after they are established.

In furrow planting each man carries his own trees, makes the slits, and sets the trees. In other methods, one man makes the slits or holes and a second one, following him, carries and plants the trees. Each planter carries his trees in a pail, basket, bag, or box. Light wooden boxes 10 to 12 inches wide, 20 to 24 inches long, and 5 to 7 inches deep, with a stiff strap for a handle, have been used to good advantage in the Lake States. The roots are surrounded by wet moss, or wet burlap if moss is not obtainable, and this should be kept moist by watering. Only enough trees for about an hour's planting should be carried at one time.

In large operations and especially when planting a brushy site, it is desirable to provide for series of flags or poles which can be set at the ends of the planting rows so that the rows may be kept reasonably straight and no part of the area missed. If furrows are made, poles or flags are not needed. The furrows can be plowed at any convenient season, but preferably well in advance of planting. Large-scale planting, covering a series of years, requires the services of a trained man to make the plans, prepare a map, organize the crews, and supervise the work. More detailed discussion of such operations will be found in Reforestation on the National Forests (*67*).

CAUSES OF LOSS OR FAILURE AND THEIR CONTROL

Many different causes of damage or failure of plantations must be considered in forming planting plans, for these can often be prevented or reduced by taking the right preventive measures in time. Such dangers include fire, animals (both domestic and wild), insects, fungous diseases, and adverse effects of weather, such as drought, extreme temperatures, frost, winter killing, and sleet and snow breakage; also poor stock and careless planting, and competition with other growth.

FIRE

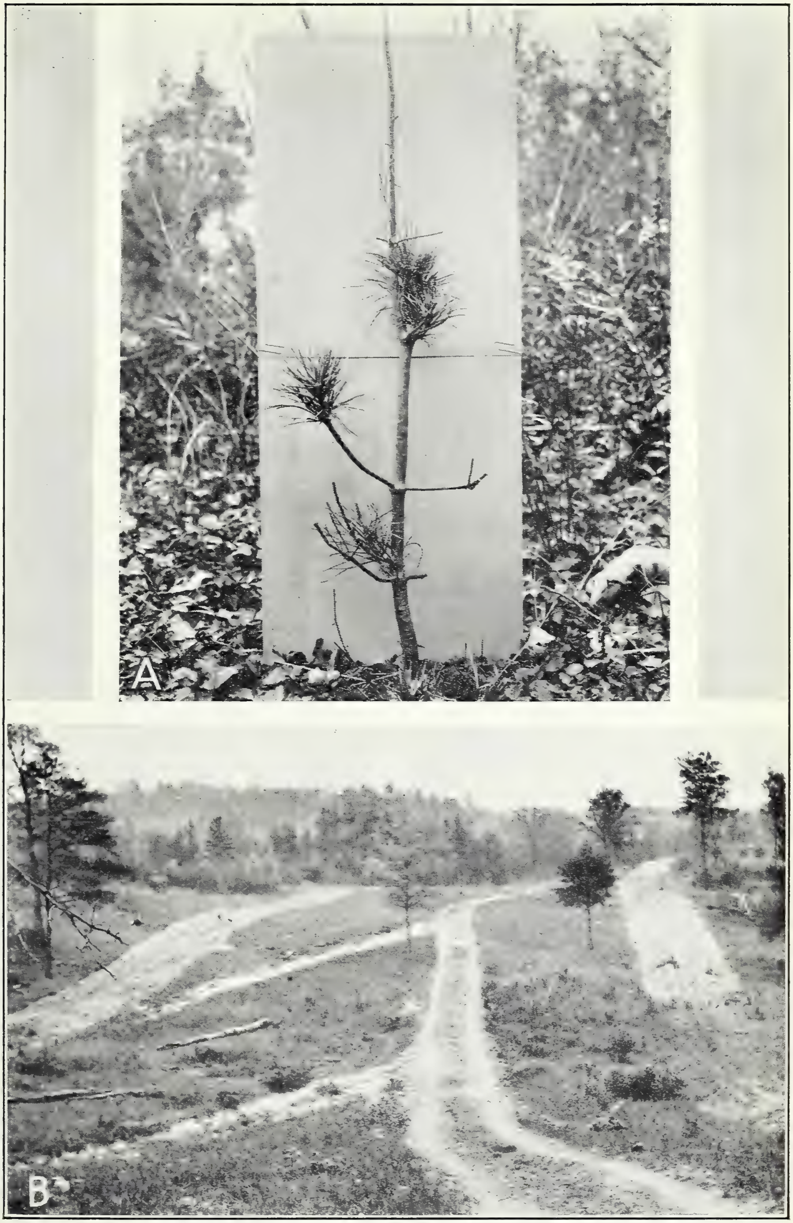
A fire, if allowed to run through a young plantation, will almost surely kill all the trees in the area. Protection from fire is peculiarly essential in the northern Lake States for the success of a forest plantation, for such plantations must occupy areas where there is more or less grass and brush to dry out to high inflammability during the dry periods of spring and fall.

The protective measures must provide for preventing fires from entering the plantation from outside as well as for the suppression of those fires which may start within. The detection of fires is now provided for in much of the forest region of the Lake States by the State or Federal Governments, or by associations of private owners, through a system of lookout towers, telephone lines, and observers. Supplementing this, there should also be some one on the ground definitely responsible for keeping fires out of the planted area.

The use of fire lines for the protection of plantations is desirable and sometimes necessary. They may be single or double. Single lines are plowed 10 to 20 furrows wide on land-subdivision lines, or along old logging railroads, or roads through the center of a strip on which the brush or tree growth is cleared to a width of 14 to 30 feet. Before plowing, it may be necessary to pull or blow out the stumps. The lines are then disked or harrowed periodically to prevent growth of grass or other vegetation. Double fire lines consist of two plowed strips of 6 to 10 furrows, 7 to 12 feet wide, located 30 to 50 feet from and on each side of a section or other subdivision line, or parallel to a traveled road. (Pl. 3, B.) The brush is usually cut on the strip between the lines so that the strip may be burned over each year and kept as free as possible from inflammable material.

Fire lines serve chiefly as barriers to the spread of surface fires, or, in case of brush or crown fires, as base lines from which back fires may be safely started. Experience has shown that straight fire lines are of the greatest value because, in fighting fire, a straight line from which to back-fire means the shortest line to watch and one least apt to cause fire fighters to become confused. Straight fire lines may also better serve as roads. Single fire lines are about half as expensive as double lines, but because of overhanging branches from adjoining planted areas they are not as valuable for fire protection. Single fire lines cost from $25 to $100 per mile where the amount of brush and stumps to be removed is not large. Double lines cost from $50 to $200 per mile under similar conditions. If single fire lines are constructed around every 40 acres, as they have been in the plantations on the Michigan State forests, where the fire protection is intensively organized, they come to 1 mile of line for every 80 acres. The acre cost for construction is then 30 cents to $1.25, and this is probably the maximum cost for this form of protection. Ordinarily, fire lines are more widely separated and the costs per acre are correspondingly lower.

The cost of disking or replowing fire lines annually varies with the age of the lines. Usually the lines are gone over twice in a season,



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RODENT DAMAGE AND FIRE CONTROL

A.—Damage by snowshoe rabbits has kept this northern white pine planted 11 years ago down to 28 inches high, with its highest living foliage only 18 inches from the ground.

B.—A double fire line along a road on the Huron National Forest.

although on old lines a single light harrowing is sometimes sufficient. Where double lines are maintained, clearing the strips of brush annually and burning the grass are usually necessary. The annual cost of harrowing with a team is $4 to $5 a mile on single lines, and on double lines, including harrowing, cutting brush, and burning grass, usually $16 to $18 a mile. Recently on the Huron National Forest the use of a tractor, with a heavy disk plow for fire-line construction and a heavy 7-foot double disk for maintenance, has been found to reduce costs below those for the same work with horses, and for annual maintenance to the low figure of $5 a mile for double lines.

Fire publicity work, particularly appeals to campers, automobile travelers, fishermen, and hunters, reduces the number of man-caused fires. Even though the people in a region are in sympathy with the forest fire-protection program and cooperate to the fullest extent in fire prevention, a workable local fire plan which will provide for prompt decisive action when fires start is always needed. The owner of a plantation who has an investment at stake can do much to increase the safety of his investment by promoting local sentiment and action for better fire protection.

CLIMATIC CONDITIONS

Critical weather conditions such as prolonged periods of drought and extreme temperatures are so important in certain years that they may be responsible for the difference between success and failure in a plantation.

DROUGHT

A drought period of more than 10 days at the time of planting or during the first season following will usually cause heavy losses among the planted trees. The sooner the drought period follows planting, especially in the spring, the more severe is the loss. From a classification of the weather conditions of the seasons in which the different plantations examined were established, it appears that the mortality in the most unfavorable years, such as 1916 in southern Michigan and 1917 in northern Minnesota, is almost certain to be more than 25 per cent and is likely to be more than 50 per cent. Apparently the loss is actually as serious when the drought follows fall planting as it is in the spring, although theoretically spring droughts should cause the heavier losses. (Fig. 4.)

In moist seasons, plantations of jack pine mixed with northern white pine resulted in a survival of 31 to 57 per cent of the jack pine and 44 to 55 per cent of the white pine. An area planted under similar conditions, except that the trees were put in in the midst of a 13-day drought in a dry fall, had only 29 per cent of the jack pine and 28 per cent of the northern white pine living. Another jack pine-northern white pine plantation planted in a dry fall in the middle of an 11-day drought had only 30 per cent of the jack pine and 34 per cent of the white pine living, as compared with 54 per cent and 50 per cent, respectively, in a plantation on the same soil where competition and rabbit damage were more severe, but no drought was experienced. An otherwise similar fall planting of the same species in a more favorable season had 70 per cent and 51 per cent, respectively, of the trees living.

HIGH TEMPERATURES

The periods of extremely high temperature which occur almost every year also cause heavy losses, although the effect of the heating is difficult to distinguish from that of drought, since the two conditions usually occur together. Air temperatures of over 90° F. result in temperatures at the surface of the soil in the sun of 110° to 130° F. Temperatures above 120° have been shown to be fatal to the life activities of protoplasm, and it is only the protection given by the bark of the trees that prevents complete loss under these conditions. Northern white pine has a very thin bark and therefore suffers most from the heat. Examples of disastrous losses from this cause are furnished by two northern white pine plantations in Michigan, where 1-year seedlings were set out in May, 1916, on sandy soils. As a result of maximum temperatures of over 90° F. in the shade on 10 or more days in late July, only 14 to 16 per cent of the trees survived. This is the chief reason why northern white pine should not be planted in exposed soils.

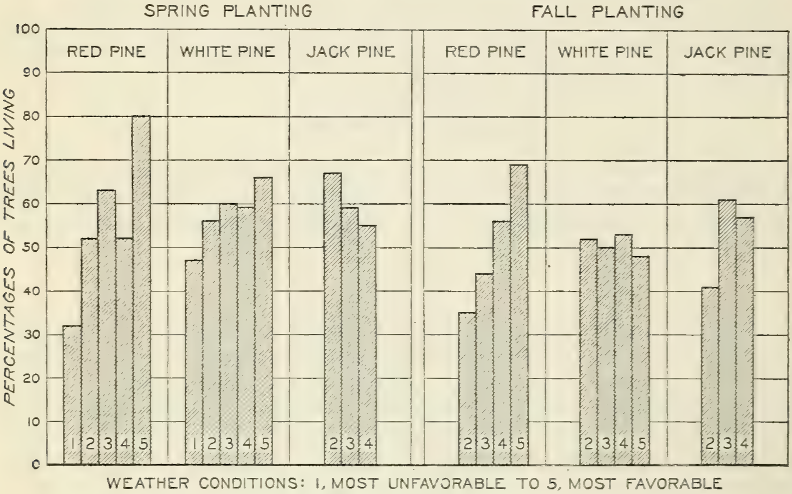

FIGURE 4.—Survival in relation to weather of season of planting

FROST, SNOW, ICE, AND WINTER KILLING

The other effects of weather which sometimes cause serious losses are late spring frost, heavy wet snows or ice which bend over and break the trees, and what is usually called winter killing. Frost damage, as with all crops, occurs in years when a heavy frost comes after growth is well started. The damage varies locally and is much more severe on low ground near swamps or stream courses and in slight depressions, or even in openings in the natural tree growth on the uplands. The evidence of this variation is plain to anyone passing through a plantation; in any moderate depression the foliage on the tips of the twigs may be brown or withered from damage caused the previous spring, or a partial or total lack of living trees may testify to similar damage in previous years. Norway and northern white pine are particularly susceptible to frost damage. Jack pine is apparently able to withstand regularly frosts which would destroy the other two pines. The damage from frost rarely if ever occurs under the cover of natural tree growth or of other vegetation.

Snow and ice breakage is infrequent and usually unimportant, but becomes serious in an exceptional storm like that of February 21, 1922, which wrecked many hardwood trees in a zone through central Michigan and Wisconsin. Winter killing may be serious in the occasional year. It occurs when a period of unusually warm weather in the winter or early spring while the ground is frozen causes the leaves of the pines and spruce, which retain their foliage through the winter, to give off moisture which the roots can not replace. The result is a browning of the needles the following spring and possibly the death of many of the trees.

In the plantations studied, the combined damage from snow and ice breakage, frost, and winter killing rarely affected more than 5 per cent of the trees in any plantation, and evidence of such damage was only noted in 4 out of the 15 Norway spruce plantations, in 11 per cent of the northern white pine plantations, in 7 per cent of the Norway pine, and in 6 per cent of the jack pine.

ANIMALS

The snowshoe rabbits in Minnesota and the adjacent part of northern Wisconsin during 1923, 1924, and 1925 caused excessive losses in forest plantations, and indeed to all young growth of forest trees. In Minnesota all of the northern white pine plantations examined were damaged, 78 per cent of the white spruce, and 55 per cent of the Norway pine. In a large number of plantations every tree which could be found had had the tip and branches cut back until only a stub was left. (Pl. 3, A.) More than half of the white pine and white spruce plantations had over 70 per cent of the trees cut back. The Norway pine plantations suffered less but apparently only because they were more often set out on the dry open sandy areas where the rabbits are less abundant.

The rabbit damage in most of Wisconsin and in Michigan is much less severe and is usually confined to the planted areas near swamps and streams. Even so, however, rabbits are among the most serious enemies of forest planting in the region. Rabbit damage was noted in 53 per cent of the Norway spruce plantations in these States, 38 per cent of the northern white pine, 8 per cent of the Norway pine, and 7 per cent of the jack pine plantations. Only rarely, however, had more than 30 per cent of the trees been injured.

There is a general impression that the rabbit population fluctuates in cycles of about seven years; that is, after they have increased to a maximum number during a 7-year period the increase of their natural enemies or some epizootic ordinarily causes them to die off in such numbers that it is another six or seven years before they regain their former abundance. Recent years in which the rabbits have been most abundant are 1901, 1902, 1908, 1914, and 1923 to 1925. On the basis of the 7-year cycle, they should have, and are reported to have decreased in numbers during 1925. When they are as abundant as they were in Minnesota in 1923 and 1924, it is a question whether planting operations should be undertaken except on the open sandy soils. The removal of the closed season on snowshoe rabbits should tend to control them somewhat, but they are not much hunted in any season in a region which abounds in more desirable game. The use of poisoned bait would probably be effective in controlling them locally on areas occupied by plantations.[6]

A thoroughly satisfactory solution of the rabbit problem has not been worked out. If it is assumed that rabbits will be sufficiently abundant to do serious damage at six to seven year intervals, it is desirable to do as much planting as possible in the year in which they die off in order that as many trees as possible may attain heights of over 3 feet and have their tops beyond the reach of the rabbits before they are seriously attacked. The period is not likely to be sufficiently long, unfortunately, to avoid much of the loss, for usually only a few of the trees in plantations of northern white or Norway pine or spruce are more than 3 feet high at 6 or 7 years of age.

Since the rabbits seem to avoid open country, trees planted in the open, in clearings, or where there is little or no brush, are less likely to be injured. An experiment at the Cloquet station showed the damage from rabbits to be much more severe under dense jack pine 15 years old than under a moderately dense 35-year stand or an open 75-year stand. In another experiment, rabbit damage was heavy on a site characterized by a dense growth of alder, willow, and aspen, and negligible on a site with a cover of sweet fern (*29*).

Deer, porcupines, mice, and red squirrels all occasionally damage forest plantations. Where deer are abundant, as in Itasca Park, they nip the needles of the pines. Porcupines sometimes girdle the northern white pines, usually up in the crown where the bark is tender; and if the girdling is complete the top dies. They may also kill the small trees, although evidence of this has not been observed. Mice have been known to girdle the trees in young plantations near the ground line under the snow. This form of damage, however, has not been evident in the Lake States. In a few plantations the buds, particularly of Norway spruce, had been eaten off. Grosbeaks in Michigan have been known to do this. Red squirrels also eat the buds and cut off the small twigs.

Further information of what measure to take to combat damage by wild animals or rodents may be obtained from the Bureau of Biological Survey, United States Department of Agriculture, Washington, D. C.

Goats, sheep, cattle, hogs, and horses should be kept out of forest plantations, to prevent damage both from their browsing the foliage and twigs and from trampling. Only a few of the plantations in the Lake States have been used for pasture and furnish examples of damage by domestic animals. The almost total failure of one plantation of Norway and northern white pine on a favorable site could be explained only as the result of the grazing of a band of sheep for two or three years after the plantation was established. Sheep and goats actually eat the foliage and are therefore likely to be more destructive than cattle or horses, which cause injury chiefly by trampling. The damage done by any kind of grazing animal in any one year may seem to be negligible, but over a period of years it is likely to mean the difference between success and failure of the timber crop. Studies in other parts of the country have shown that the degree of damage depends largely on the number of stock per unit area, and the way they are handled, the damage being greatest where they bunch together. The damage in a pasture which is overgrazed and where the feed becomes scarce is much greater than where the grass and more palatable herbage are abundant. It has been suggested that grazing is an advantage because it keeps down the grass and inflammable material and thereby reduces the danger of destruction by fire. This is undoubtedly true, but the risk of fire loss is not believed to be greater where reasonable protection measures are provided than the possibility of serious loss of the planted trees through pasturing of domestic animals of any kind.

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[6] The Bureau of Biological Survey (*20*) has suggested the scattering of poisoned bait in early spring a few hours before sunset along the rabbit trails and in openings. The recommended poison mixture consists of 1 ounce strychnine sulphate, 1 teaspoonful saccharin, and ½ cup gloss or laundry starch in 1 quart of water. The strychnine and saccharin are dissolved in the water by boiling, the starch, already softened with cold water, is added, and the boiling is continued until the solution thickens. Fifteen pounds of twigs of native brush—aspen, for example—cut in 2 or 3 inch lengths, are coated with the mixture, which is then ready for immediate or later use. There are serious objections to this method, however, in a region where desirable game animals would also suffer from the distribution of the poison.

INSECTS

Insect damage to forest plantations appeared to be comparatively slight. In the plantations from 5 to 20 years old, only rarely was a tree found which was damaged by insects to the extent that it was likely to die. Jack pine appeared to be the most susceptible, 82 per cent of the plantations examined having been attacked. In many of them almost all of the trees were or had been infested by the jack pine form of the spruce budworm, which attacked the new twigs in the early summer.

Northern white pine is frequently attacked by the white pine weevil. The larvae feed on the terminal shoot under the bark and kill it. One or more of the side branches then become leaders, with the result that growth is retarded and the trunk usually develops a crook or fork. Forty-two per cent of the white pine plantations examined bore evidence of this insect, but rarely were more than 10 per cent of the trees attacked and in no case more than 20 per cent. Graham in a study of the weevil (*25*) concluded that, to avoid serious damage, northern white pine should be maintained in dense stands. Pierson, in New England, (*51*) came to the same conclusion and also suggested that northern white pine be grown in mixture with hardwoods such as oak, maple, and ash, the northern white pine to form not more than 20 to 25 per cent of the larger trees in the stand.

Forty-seven per cent of the Norway spruce plantations bore evidence of damage by insects of one kind or another. A few of them were heavily infested by the spruce gall aphis (*Chermes* sp.), which causes a gall-like growth at the tips of the twigs.

Norway pine is the least subject to insect damage of any of the planted species. Insect work was noted in only 12 per cent of the plantations. Only rarely were more than 2 per cent of the trees affected and then only slightly.

The plantations of white spruce were still small and had not been attacked by insects. The spruce budworm which has been so destructive in the natural stands of balsam fir and spruce in northern Minnesota is much less likely to attack stands of white spruce on upland sites where balsam fir is not associated with the spruce, since the insect prefers the balsam fir. The danger is still further reduced when the white spruce is planted in mixture with northern white or Norway pine.

The larch sawfly has almost completely destroyed the larger timber of native tamarack in the region. The tamarack is more likely to be able to survive this damage when it is planted on upland sites. This insect also attacks the European larch.

Grasshoppers may prove very destructive to young plantations just established and are liable to be more serious in dry years. In one year fall planting on the Michigan State forests had to be terminated because the grasshoppers ate the seedlings as fast as they were planted.

The larvae of the June beetle, commonly known as white grubs, undoubtedly cause some mortality in many of the plantations by cutting off the roots before the trees are well established. In the eastern part of the northern peninsula of Michigan, heavy losses in plantations have been ascribed to this cause. On the Minnesota National Forest, also, the white grubs do considerable damage. Elsewhere, however, the damage has not been excessive.

Ants have been known to kill patches of pine in plantations, and occasional trees were noticed, usually northern white pine, which may have been killed by them. They are not, however, a serious cause of damage.

If insect damage is found in forest plantations, specimens of the insect and its work should be collected and sent to the representative of the Bureau of Entomology, United States Department of Agriculture, who should be addressed as Forest Entomologist, School of Forestry and Conservation, University of Michigan, Ann Arbor, Mich. He is prepared to identify the insect and recommend measures for its control.

FUNGUS DISEASES

Fungi are a minor cause of damage in the plantations in the Lake States to-day. The most dangerous one is undoubtedly the white-pine blister rust, which attacks and kills white pines. No damage from this fungus was observed, however, in the plantations examined. Trees may be protected from it by eradicating all current and gooseberry bushes within 900 feet of the plantation. White pine should not be planted within a mile of black currants (*R. nigrum* L.) Where currants or gooseberries are so abundant as to make the cost of their eradication prohibitive, species other than northern white pine should be planted.

Jack pine is subject to a stem rust (*Cronartium cerebrum* (Peck) Hedgc. and Long) which causes bulb-like swellings on the branches. Only occasional branches and trees are infected, however, and the damage is not serious. Eight per cent of the jack pine plantations had 1 or 2 per cent of the trees infested.

Fungus diseases in the plantations of the other species were negligible. The United States Department of Agriculture, Bureau of Plant Industry, Office of Forest Pathology, Washington, D. C., or the State botany or plant pathology departments are prepared to identify and give advice on the control of tree diseases.

POOR STOCK AND CARELESS PLANTING

Careless planting and poor condition of the trees when planted may often be more serious causes of loss in forest plantations than those which have been mentioned. Information on the care of planting and the quality of the stock was obtainable only for part of the plantations and was mostly based on a more or less hazy recollection going back over several years. It is almost certain, however, that, except in the occasional very favorable year, there is some loss from these two causes. Tree roots may be injured or partly broken off when the trees are dug in the nursery, or they may dry out or become heated if there are delays in shipment, or they may dry out after they are received and before they are planted.

Nursery operations, both public and private, are usually well managed and at the present time produce good planting stock, so that the loss due to poor condition of the stock when received is likely to be small, probably not over 5 per cent. Grading of the trees as they are dug in the nursery is not generally practiced. If grading were practiced it would be possible to transplant and save the 10 to 30 per cent of the trees which because they are poorest are most likely to die when set out, particularly if the season following planting is unfavorable or the planting site is not of the best.

Exposure of the trees even for one hour or less before planting and consequent drying of the roots have been found to result in heavy losses. Exposure is worse in the sun than in the shade (*27*), and damage is greater in the spring than in the fall (*79*). Even 10 to 20 minutes exposure on a windy day may be serious. This is an all too common cause of large losses, which are inexcusable because they can be so easily avoided by keeping the roots moist until they are in the ground.

Careful planting is largely a matter of the experience and care of the man in charge and the members of the planting crews. Where the planting is done by experienced crews the loss from this cause is unquestionably less than 5 per cent, even when the men are under pressure to work fast and keep down the cost. On the other hand, if the planting is done by inexperienced men the trees are likely to be set too deep or too shallow, or the soil to be not well firmed around the roots, practices involving heavy losses. Where experienced planters are not available, ordinary laborers must be placed under the thorough supervision of a competent man and taught to plant carefully. In this way the results may be as good as with an experienced crew, although, until the men become used to the work the rate of planting will be slower and the cost higher.

COMPETITION

The effect of competition between the planted trees and natural tree growth, shrubs, brush, and other vegetation was studied in some detail. The term competition is used to express the effect upon the planted trees of the demands of other closely adjacent trees, brush, or sod for the same space, light, soil moisture, and soil nutrients. Although soil moisture is probably the most important of the elements in the competition, no attempt will be made in this discussion to distinguish between the elements.

It is evident in all the plantations that trees planted under the crowns of larger trees already established grow slowly. Many trees so planted died or were in poor condition and seemed likely to die. Outside the ground area covered by their crowns the effect of the larger trees on the growth of the planted trees was slight. Jack pine is least able to survive this competition. Norway pine survives better than jack pine but usually not satisfactorily for more than about 10 years after planting. Northern white pine, white spruce, and Norway spruce survive well in competition with trees which shade them, but their growth is comparatively slow.

The only plantation studied in which northern white pine exceeded Norway pine in height growth where the two species were planted under identical conditions was one in which the natural tree growth covered 50 per cent of the area. The average annual growth of the white pine was 0.18 foot and of the Norway pine 0.14 foot. If the average annual height growth of all the trees in the plantations of the northern white pine be taken as 1, that of the pines planted under larger competing natural growth will be represented by 0.90. For Norway spruce, the relation is 1 to 0.76; for Norway pine 1 to 0.58; and for jack pine 1 to 0.56. In other words, jack pine is most retarded (its early height growth being reduced almost one-half) by the competition of other trees, and northern white pine is least affected and then only to the extent of one-tenth. (Fig. 5.)

The effect of competition on the percentage survival is more complicated than its effect in retarding growth, because conflicting influences are involved. During the first few years the competing vegetation protects the planted trees from excessive heating and thus may save many of them from death at critical times. On the other hand, competition deprives them of light, moisture, and nutrients and in this way causes losses which tend to become heavier as the trees grow larger and the struggle for life becomes keener.

Other elements in the effect of competition include the kind and density of the competing natural tree growth. Of the common trees occurring naturally on planting areas, the competition of jack pine is more serious than that of aspen, which in turn is more injurious than that of the oaks. Even a stand of jack pine may not always be prohibitive, however, for in an experiment at Cloquet such a stand did not prevent a northern white pine underplanting from having at 12 years a 90 per cent survival. The influence of density of the natural tree growth is indicated by experimental plantings by the Cloquet Forest Experiment Station in Minnesota (*29*), in which northern white, Norway, and Scotch pines were planted under jack pine stands of three different densities. Survivals after five years were highest in the 70-year open stand, next in the 35-year dense stand, and poorest in the 15-year dense stand. The northern white pine had the largest proportion living, with successively smaller percentages of Scotch pine and Norway pine.

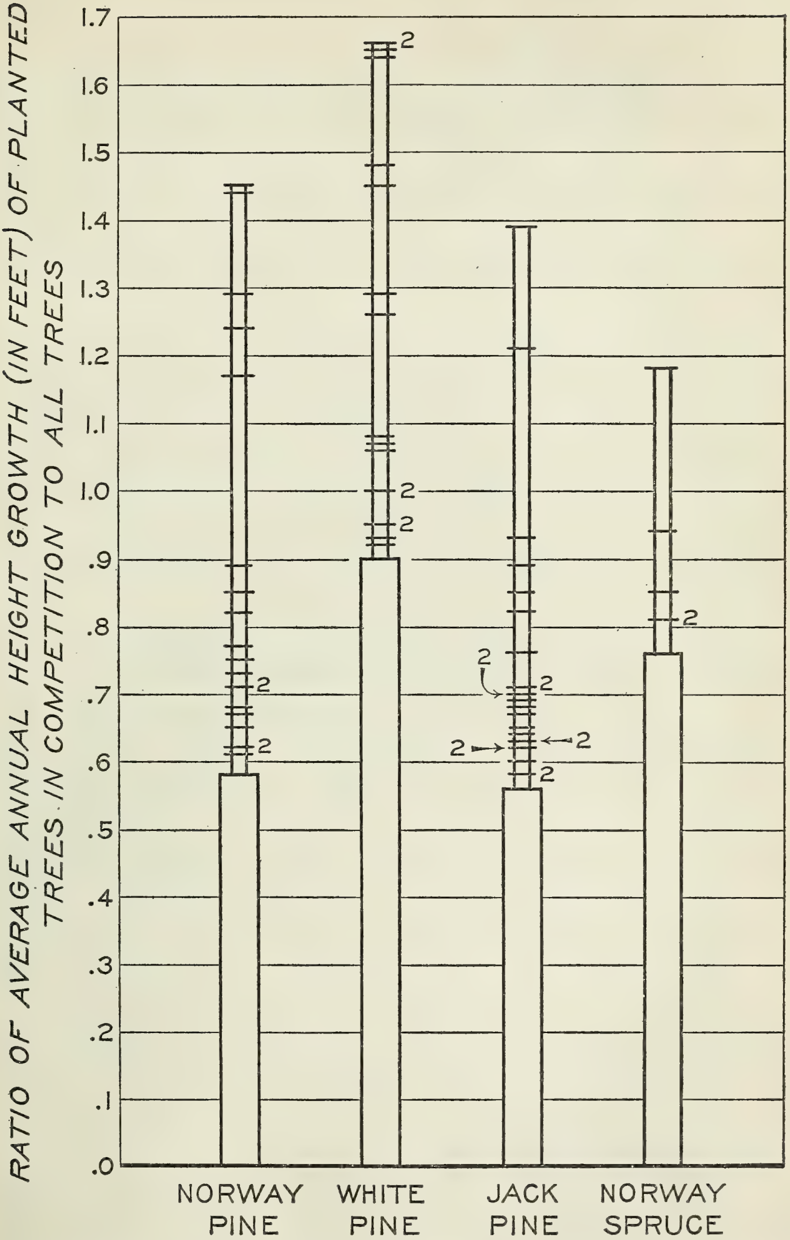

FIGURE 5.—Effect of competition of natural tree growth on the height growth of planted trees. Wide bar marks average of all plots; single plots that attain more than the average are notched on narrow bar, numerals indicating two or more plots of the same height

The effect of grass and other low vegetation on the planted trees is not as well marked. It has been brought out that furrow planting or the removal of a square of sod in slit planting results in somewhat better survival and that the difference is probably due to the elimination of the root competition of the grass and brush for the first few years. It is generally stated and it seems reasonable to believe that the competition of sod for moisture causes losses of the planted trees. In this study, however, the percentages of the trees living in plantations with different quantities of sod, sweet fern, blueberry, brake fern, hazelnut, or raspberry do not show significant differences. The results on sites where the hazel was thick were usually poor, but this was due partly and perhaps chiefly to the damage by rabbits, which abound on such areas, rather than to the direct competition of the hazel.

Shade of the natural vegetation may sometimes be more beneficial to the planted trees than the competition of its roots is detrimental. Although this effect did not appear in the study of plantations in the Lake States, it has been demonstrated by 2–1 stock in experimental northern white pine plantations in Massachusetts (*42*) where 57 per cent without shade lived, and 85 per cent with some shade. Similar tests with 2–0 stock yielded 33 and 69 per cent respectively. Root competition accounted for 10 per cent of the loss of the unshaded; and of the shaded, 20 per cent. The removal of the grass in July in a northern white pine plantation in New York (*50*) resulted in heavy losses, attributable directly to the exposure.

The areas occupied by patches of mosses and lichens, which are frequently found on the dry sandy sites, are apparently extremely unfavorable to the establishment of planted trees, the mosses and lichens themselves or the soil conditions presumably preventing other forms of vegetation from becoming established there. For example, a mixed plantation of Norway and jack pine on an area with 35 per cent cover of moss had only 21 per cent of the trees of each species living, whereas a plantation under otherwise similar conditions but without the moss had 59 per cent of the jack pine and 50 per cent of the Norway pine living. Whatever the cause, living trees were rarely found in these patches of moss, and a plantation with much of its area occupied by the moss had a correspondingly low survival of trees.

A thick growth of laurel, such as is characteristic of some low sandy soils, is also unfavorable to the establishment and growth of plantations. Only 25 per cent of the jack pine and 40 per cent of the Norway pine remained in a mixed planting of the two species under a 45 per cent cover of laurel, whereas a similar planting without the laurel had 48 per cent and 56 per cent of the trees living. The average annual height growth with the laurel was 0.33 foot for jack pine and 0.23 foot for Norway pine, and without the laurel 0.56 and 0.31 foot, respectively.

The combined effect of all the foregoing causes, including weather, fire, animals, insects, diseases, careless planting, poor stock, and competition, has resulted in losses of not more than 10 to 50 per cent of the trees. On the whole, therefore, no one of these causes, which are often indistinguishable, can be said to be prohibitive of forest planting in the Lake States.

THINNING, PRUNING, AND INTERMEDIATE CUTTINGS

More trees are planted in forest plantations than will live to be harvested in the final crop, and it is therefore desirable to thin out some of them, unless losses have been so heavy or the spacing is so wide that less than 400 or 500 trees to the acre remain. Assuming that there have not been heavy losses, a certain proportion of the trees should ordinarily be cut before the competition between them becomes so severe that considerable numbers are dying naturally.

If the trees are spaced 6 by 6 feet, a first thinning should be made when they are about 25 years old. At this age, the trees will be from 1 to 7 inches in diameter, and only a few of those which are cut will be large enough to be otherwise marketable, but they probably will have sufficient value locally for fuel to pay for the cost of cutting them. The benefit of the operation will then come in the increased growth and improved quality of the remaining stand.

With 8 by 8 foot spacing, thinning does not become necessary until the trees are 40 or 50 years old, but at that time the product of the thinning will undoubtedly be merchantable for pulpwood or fuel and will bring a small profit over the cost of the operation.

Plantations spaced 5 by 5 feet or closer should be thinned when they are about 15 years old and before they will yield marketable wood material. (Pl. 4.) Thinnings in spruce of this age can usually be marketed at a good profit in December for Christmas trees.

As there are several methods of making thinnings, the advice of a forester[7] should be obtained to assist in marking the trees to be cut. As a general principle, thinnings should be made lightly and frequently, even though the procedure is often not feasible economically. In Germany thinnings are made every 10 years and give 25 per cent of the net profit from the whole forest crop. Always in a thinning operation, trees which show evidence of disease or insect work or are crooked or broken should be removed.

Pruning the trees in forest plantations by cutting off the dead and lower green limbs with a saw or ax is sometimes practiced. If an ax is used, the branches should be cut from beneath by upward strokes to avoid splitting. The branches should be trimmed close to the trunks so that the new wood that will form over the branch scars will be without knots, making the lumber of higher value. Since logs for sawing are usually cut in 16-foot lengths, pruning for the production of high-quality logs should be to a height of 17 feet from the ground. This can be done for the higher branches by attaching a saw to a pole. Only the 200 or 300 trees to the acre which are most vigorous and will make up the final timber crop need be pruned.

The effect of the pruning on the quality of the timber was demonstrated in a northern white pine stand in New Hampshire (*11*, *43*). The best trees, which were to be kept for the final crop, were pruned when they were 3 or 4 inches in diameter. After 20 years they had added sufficient clear wood to make cutting profitable. The owner of this area found that the pruning increased the value of his lumber about $40 a thousand board feet. The same owner concluded that it did not pay to prune Norway pine.

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[7] Lists of names and addresses of consulting foresters are sent out by the Forest Service, United States Department of Agriculture, Washington, D. C., upon request.

In an unpruned pine or spruce plantation during the first 15 years the limbs have needles almost to the ground, and the risk of complete destruction if fire gets started in the plantation is great. Pruning unquestionably reduces this fire risk. But pruning costs from $5 to $20 an acre, or as much as the planting of the trees in the first place. So large a cost is not justified as a protection measure, because effective fire protection can be obtained at much lower cost by the construction of fire lines and the maintenance of a fine-protective organization during dangerous seasons. Pruning for protection can only be justified over small areas where it may be done in spare time by an owner himself or by a fire guard on rainy days, the cost thus being only incidental.

As a means of increasing the value of the timber, if the results obtained in New Hampshire with northern white pine are applicable elsewhere, pruning is amply justified; though there is always the chance that the wounds made by cutting the branches may result in attacks and losses from insects and diseases which might offset the increased value due to improved quality of the product. Pruning is chiefly desirable in plantations which are widely spaced or composed of trees, like northern white pine, which do not shed their branches easily.

Cuttings to release planted trees will be needed on cut-over lands where hardwood stumps sprout or where there is a natural growth of aspen, paper birch, oaks, jack pine, or other trees which have a start over the planted trees or grow more rapidly than they can during the first few years and are likely to crowd them out. Northern white pine and the spruces will ordinarily suffer only a little retardation of growth, and the plantations may even benefit from overhead shade by increased survival until they are 15 or 20 years old and 5 or 10 feet high. About that time the larger natural growth of other species should be cut. If the brush is dense, however, and the planted trees are being damaged, it may be wise to release them within five years after planting.

In plantations of jack and Norway pine, any competing natural tree growth should be cut as soon as possible so that the planted trees may have the benefit of ample light and space for their roots. Faster-growing hardwoods that appear about the time of planting and are likely within the next 10 years to damage the planted trees by crowding them and by whipping back and forth in the wind should be removed while they are still small, when the operation can be done most cheaply. It is not safe to wait until the hardwoods are of merchantable size. The best time to remove them is when they are still so small that a man with an ax or brush hook can cut them off with a single stroke for each stem. At the time the cleanings are made, any of the planted trees which are diseased or badly infested with insects should also be removed. This first release cutting or cleaning, usually made when the plantation is 3 to 5 years old, should be repeated five years later and if needful at intervals thereafter until the planted trees are as tall as the competing growth. Trees of desirable kinds which occur naturally on the area and are not interfering with the planted trees should be left to form a mixed stand.

The cost of cleaning varies with the number of stems to be cut and may require from one hour to two days of one man's time to the acre. The cost will therefore be from 50 cents to $7 an acre. Even as much as $15 an acre may pay (*30*). Fisher (*22*) (*23*) on the Harvard Forest in Massachusetts has made cleanings to release young pines at a cost of $2 to $5 an acre for each cleaning and considers that there will be a gain in the crop value at maturity of $250 to $325 an acre over similar pines unreleased from competition with inferior hardwoods.

COST OF PLANTING

There are four elements in the cost of planting forest trees; namely, the nursery stock, the planting operation, the maintenance and protection of the plantations, and the taxes on the land.

NURSERY STOCK

High-quality nursery stock for forest planting can usually be obtained at low price from the State nurseries in Michigan and Wisconsin, if ordered for planting within the respective State boundaries. Applications should be addressed several months in advance of the time of planting as follows:[8]

Michigan: Department of Conservation, Lansing, or Department of Forestry, Michigan State College, East Lansing.
Wisconsin: Conservation Commission, Madison.

If the kind or amount of stock desired can not be supplied by the State nursery, the Forest Service, Washington, D. C., will furnish to any one on request a list of dealers in tree seeds and seedlings with whom orders may be placed.

Commercial dealers and nurseries in the region ordinarily supply a demand for ornamental and orchard planting stock in small numbers and large sizes at costs that would be prohibitive for forest planting. It might be possible, however, to obtain stock from commercial nurseries at a cost low enough to make forest planting profitable if a large order could be given far enough in advance to enable the nursery to grow the trees from seed for the two or three years until they were ready to be planted. Price quotations should be obtained from several different dealers before an order is placed.

If one has the time and attention to give to it or if large quantities of stock are needed, there are advantages in raising the nursery stock locally from seed. In this way stock of the desired kind and size is ready when wanted for planting. Since the stock is at or near the planting site, the danger of loss from delay in transit is avoided. Locally grown trees are also best adapted to the local climatic and soil conditions. Economical and successful nursery operation, however, requires that a trained man be in charge, and such a man will usually be interested only if year-long employment is provided. Large-scale production is almost necessary to justify the overhead expense; but the cost of producing the stock on a large scale may be expected to be less than the price at which it can be obtained from any other source.

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[8] In Minnesota the only State nursery is that of the Cloquet Forest Experiment Station at Cloquet. No distribution for forest planting is made by that State.

The stock raised in small home nurseries has most of the advantages of any other locally grown stock, except that it is likely to be more expensive. However, anyone who wants to do some planting on a small scale and has spare time for it will find the nursery work thoroughly interesting, even though it may not be wholly successful until experience has been gained.

If any one company or individual is not in a position to operate a nursery on an economical scale, the same advantages may be obtained by the establishment of a joint nursery to supply the needs of a group of landowners in the same district. Similarly, with increasing recognition of forestry enterprises as appropriate county and city activities, it may be well to consider the establishment of communal forest nurseries to provide stock for planting on county or city forests and also for distribution at low cost to local owners of forest land in need of planting.

Seed for any nursery should be collected from trees growing as near the nursery or planting site as possible. Stock from seed gathered in a region of different climatic conditions is likely to produce a less satisfactory crop of trees than that from local seeds. Even the difference between seed from southern or northern Wisconsin may be important.

Nursery practice is not discussed in this bulletin. Good directions for nursery practice may be found in publications of the United States Department of Agriculture and in other publications (*66*, *67*, *68*, *69*, *70*).

PLANTING OPERATIONS

The cost for any individual planting operation depends on the conditions on the area to be planted. Three methods of forest planting have been previously described: (1) The hole method, by which a hole is dug for the tree with a spade or mattock; (2) the slit method, by which the trees are set in slits where plowing is impracticable; and (3) the slit-furrow method, by which the trees are set in slits in the bottom of plowed furrows. Labor is the largest cost element in these operations, varying locally, seasonally, and annually in this region in the last few years from $2 to $4.50 a day. An average cost of $3.50 a day has been used as a basis for the following cost figures. By slit-furrow method a man may be expected to plant 1,500 to 2,000 trees in a day, although records as high as 2,900 to 3,100 have been made by crews on the Huron National Forest. The cost of planting exclusive of plowing by this method will be from $2.50 to $3 a thousand trees. In these and the following costs, about one-third of the labor cost has been added for supervision and equipment. By the slit method a man will plant 1,000 to 1,200 trees in a day, and the cost will be from $4 to $4.50 a thousand trees. The hole method is the slowest, and 400 to 600 trees per man per day at costs of $8 to $11 a thousand are representative.

Obviously, the number of trees to the acre directly affects the planting cost on an acre basis. In the slit-furrow method the distance between furrows and, therefore, the amount of furrow to be plowed also affects the cost. The costs per acre of planting 1,740, 1,210, and 680 trees to the acre for the different species, classes of nursery stock, and methods of planting are shown in Table 5.

TABLE 5.—*Costs of planting different species by slit-furrow, slit, and hole methods with different spacing*

Planting stock and method of planting	Trees set per man per day	Cost of setting per 1,000 trees[1]	Cost per acre according to spacing[2]		
			5 by 5 feet	6 by 6 feet	8 by 8 feet
Jack pine, 1–0 stock at $1.50 per M:	*Number*				
Slit-furrow method	2, 000	$2. 50	$7. 96	$5. 69	$3. 37
Slit method	1, 200	4. 00	9. 57	6. 66	3. 74
Hole method	600	8. 00	16. 53	11. 50	6. 46
Norway pine, 2–0 stock at $3 per M:					
Slit-furrow method	2, 000	2. 50	10. 57	7. 50	4. 39
Slit method	1, 200	4. 00	12. 18	8. 47	4. 76
Hole method	600	8. 00	19. 14	13. 31	7. 48
Northern white pine, white spruce, and Norway spruce 2–1 stock at $5 per M:					
Slit-furrow method	1, 500	3. 00	14. 92	10. 53	6. 09
Slit method	1, 000	4. 50	16. 53	11. 50	6. 46
Hole method	450	10. 50	26. 97	18. 76	10. 54

[1] Cost of furrow in slit-furrow method not included.

[2] For slit-furrow method, $1, 85 cents, and 65 cents added according to spacing for cost of plowing, based on 8 miles of furrow in a day plowed by a man and team at $5.

Taking into consideration all of the variable elements of cost in the planting process alone, there is evidently a wide range in total cost. Table 5 indicates a minimum of $3.37 per acre for small jack pine stock planted by the quickest method on an easy planting site, and with a comparatively small number of trees to the acre. Actually, during the six years, 1920–1925, 10,483 acres of the sandy lands of the Michigan National Forest were planted, 680 trees to the acre, chiefly with 2-year Norway pine seedlings, at an average cost of $3.43 an acre. At the other extreme, 3-year transplants of white pine or spruce planted at the rate of 1,740 trees to the acre by the hole method would cost about $27 an acre. Costs as high as this or higher have not been uncommon in small-scale planting operations in the region where inexperienced men did the work under instructions which demanded careful planting, even at the sacrifice of speed. Planting units of 500 or 1,000 or more acres are desirable in order that the cost per acre may be kept to a minimum.

PROTECTION FROM FIRE

Protection from fire is an essential current cost in every forest plantation in the region. The cost of the construction of fire lines at the time of planting is usually less than 50 cents an acre. The disking and clearing of the fire lines and the employment of men to be on the ground during the dry seasons to insure care with fire by persons in or near the plantations and to put out any fires which may start are the chief elements of current cost. Lookout towers, telephone lines, and other detection measures have not been included, since the States provide with increasing effectiveness for this part of the protection. The probable annual cost to the private owner of protecting his plantation may therefore be placed at 5 cents an acre a year. It may exceed this amount for an owner of a small area who has to hire a man on full time during the fire season, but it will almost certainly be less for the owner or group of owners who organize protection for large areas. For the State or Federal Government protection must include other items, such as detection, and these may raise the costs sometimes to as much as 10 or 15 cents an acre. Actual costs on the Michigan and Minnesota national forests are 9 cents and 4 cents an acre, respectively. Ordinarily fire protection is the only maintenance cost except for the occasional expense of cleanings or cuttings in areas where there is considerable brush or natural tree growth competing with planted trees.

TAXES

The taxes on cut-over and denuded lands in the Lake States vary from 5 or 10 cents to 85 cents an acre. They are less on the sandy land of the southern peninsula of Michigan where the frequent failure of attempts at farming over a period of years have generally proved the land's low value, and they are higher in the developing portions of northern Wisconsin and Minnesota where there is still some optimism in the matter of land settlement and development. An average figure for the tax on cut-over land in the northern Lake States is probably about 35 cents an acre annually. Although this rate is not always prohibitive to forest planting where other conditions are favorable, the difference between 35 cents and 10 cents for large areas in the Lake States may, under present economic conditions, mean the difference between a profit and a loss in the results of the planting operation.

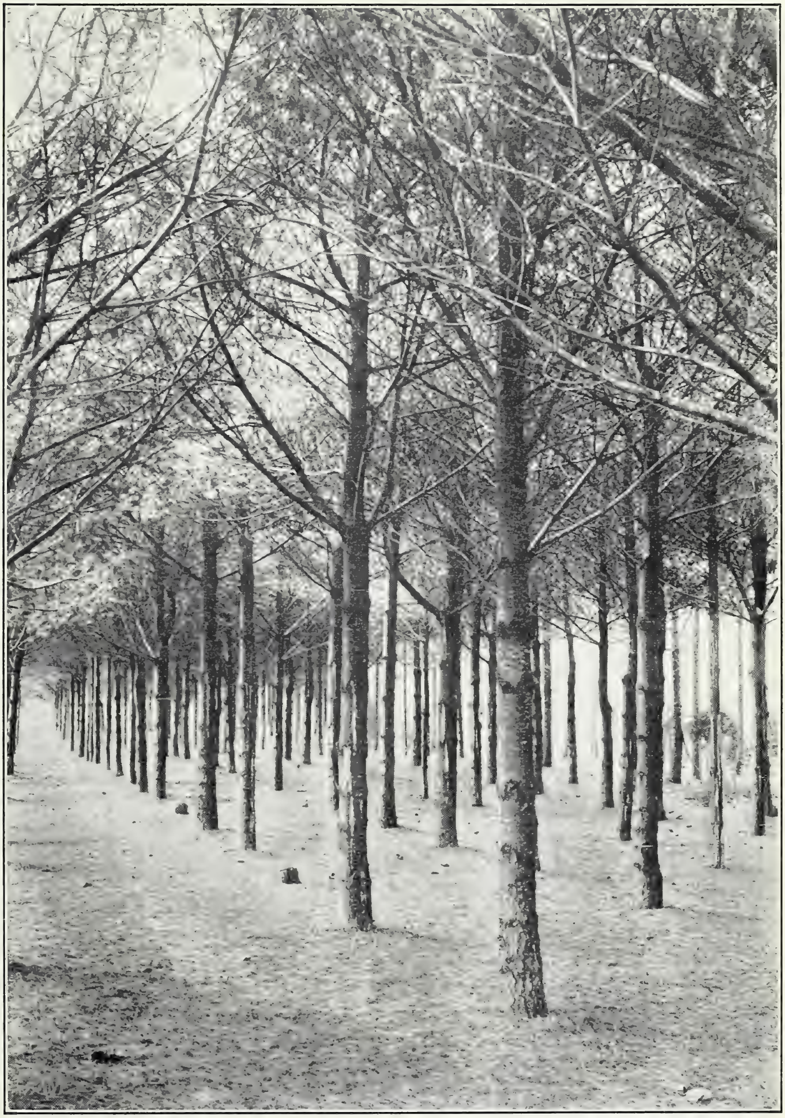
GROWTH OF PLANTATIONS

Since the plantations in the northern Lake States have not yet reached an age or size to be cut and marketed, definite figures on growth and yield can not be obtained. It has been necessary to estimate their future yield by making comparisons of their growth during the first 10 to 25 years with natural growth, and with the growth of plantations of the same species and ages in other regions.

GROWTH IN HEIGHT

For the first 10 years jack pine grows the fastest in height, Norway pine next and a little faster than northern white, and white and Norway spruce somewhat slower than northern white pine. (Pl. 5.) The comparisons between species are brought out in Figures 6 and 7 and in Table 6. Jack pine reaches twice the height of Norway or the white pine during the first 10 or 15 year period, when these species are characteristically slow of growth, but after that period it does not increase its lead at the same rate, if at all. Scotch pine (fig. 6) grows only a little less rapidly than jack pine and on the cultivated soils even faster. However, nearly all of the older plantations of Scotch pine in the region are so crooked and so limby that it is doubtful if they will ever be used for anything but firewood, and this is likely to be the outcome of planting Scotch pine in any instance unless extreme care is used in obtaining seed of northern origin. Furthermore, this species has no advantage over the native jack pine on extremely poor sands, and should be used only on reasonably good sites.

The averages for the spruces and larch are based on so few plantations that they only serve to indicate comparatively slow height growth during early life.



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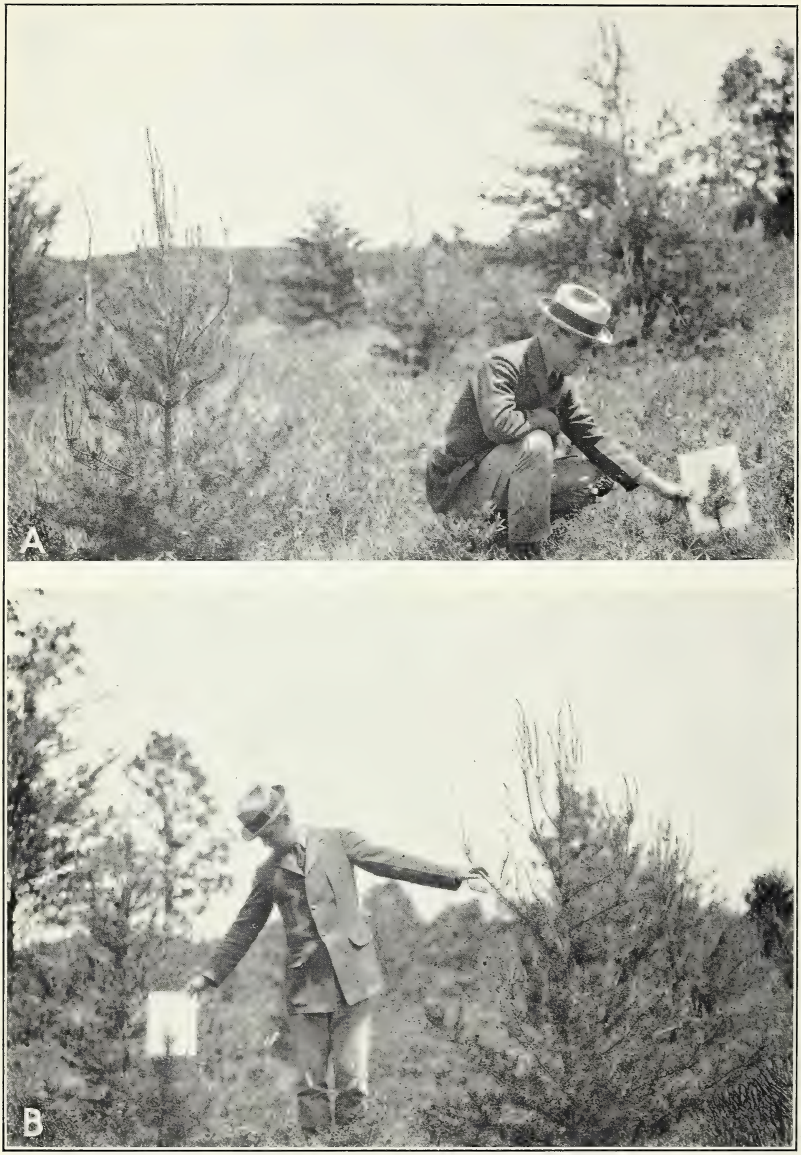
PRODUCT OF FOREST PLANTING

A northern white pine plantation 22 years old, thinned when it was 15 years old. The trees have also been pruned.



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COMPARISON OF GROWTH BY SPECIES

A.—Jack pine 6 feet high and northern white pine 1 foot high planted at the same time in 1918 on open sandy site.

B.—Norway pine 2 feet and jack pine 7 feet under similar conditions.

The height growths for the different species and conditions indicated by the wide bars in Figure 6 are made up from the averages of the individual plantations of which those above the general average are indicated on the narrow bars. A glance at them shows that there is wide variation in the height growth of different plantations of the same species growing under similar conditions. The maximum height to the nearest foot of any one plantation for each condition of site and competition is shown in Table 6. The poorest growth is

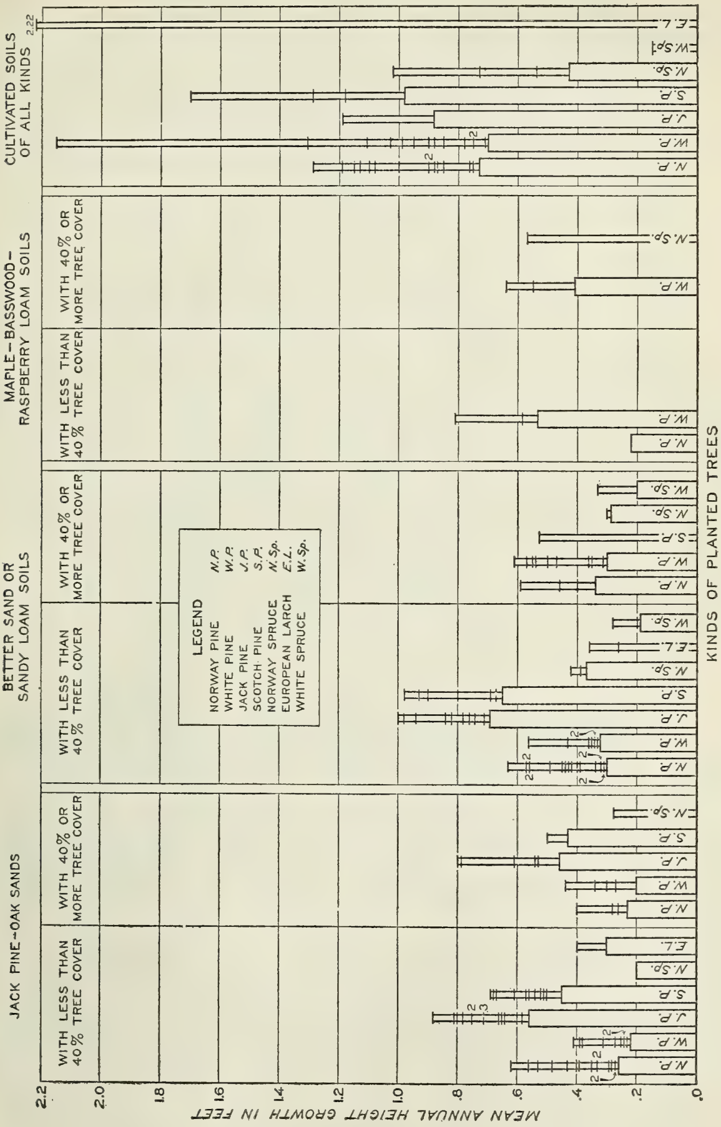

FIGURE 6.—Height growth of different kinds of planted trees. Wide bar marks average of all plots; single plots that attain more than the average are notched on narrow bar, the numerals indicating two or more plots of the same height

about 0.1 foot a year for all species and conditions. These rather uniform minima are due usually to some cause other than site or competition, such as cutting back by rabbits. The slow growth of several of the northern white pine plantations and consequently the low average height growth of that species on the better sandy soils under 40 per cent or more of cover is also the result of damage by rabbits or other agencies.

TABLE 6.—*Average and maximum height at 10 years of different kinds of planted trees under different soil and cover conditions*

NATURAL TREE GROWTH COVERING LESS THAN 40 PER CENT OF AREA

[Heights in feet]

Species	Average height				Maximum height			
	Jack pine-oak sands	Better sands and sandy loams	Heavy soils	Cultivated soils	Jack pine-oak sands	Better sands and sandy loams	Heavy soils	Cultivated soils
Jack pine	5.6	6.9		8.8	9	10		12
Norway pine	2.6	3.0	[1] 2.2	7.3	6	6	[1] 2	13
Northern white pine	2.2	3.2	5.3	7.0	4	6	8	22
Norway spruce	2.0	3.7	[1] 5.7	4.3	2	4	[1] 6	7
European larch	3.0	3.1		[1] 22.2	4	4		[1] 22
White spruce		1.9		1.5		3		2

NATURAL TREE GROWTH COVERING 40 PER CENT OF AREA AND MORE

Species	Average height				Maximum height			
	Jack pine-oak sands	Better sands and sandy loams	Heavy soils	Cultivated soils	Jack pine-oak sands	Better sands and sandy loams	Heavy soils	Cultivated soils
Jack pine	4.6				8			
Norway pine	2.3	3.4			4	6		
Northern white pine	2.0	3.0	4.1		4	6	6	
Norway spruce	[1] 2.8	2.9			[1] 3	3		

[1] Only one plantation.

Occasionally a plantation makes exceptionally rapid height growth. The two most striking examples are the plantations of European larch and northern white pine which grew at the rate of 2.22 and 2.16 feet a year, respectively. Both were at Green Lake, Wis. Large stock was planted on good soil and cultivated before and after planting. The favorable climate at the southern edge of the region probably contributed also to the unusual growth. Individual trees in certain years grow surprisingly fast, as did the white pine shown in Plate 6, A.

The average heights of jack pine 10 years after planting on the different sites, specified in Table 6 and Figure 7, are 9 feet on cultivated soils, 7 feet on the better sandy or sandy-loam soils, and only 5 to 6 feet on the dry jack pine-oak sands. Norway and Northern white pine are closely similar in their early height growth. On cultivated sites even when the soil is sandy and dry, they reach heights of 7 to 8 feet in 10 years. On the loamy soils where the competing growth covers not to exceed 40 per cent of the area, the height at 10 years is usually between 5 and 6 feet. On the better sandy soils or on the heavy soils where there is more than 40 per cent competition of natural tree growth, they will average between 3 and 4 feet in height in 10 years. The spruce plantations are few, and most of them have been so damaged by rabbits that satisfactory conclusions as to the growth on different sites are not possible. However, the range is from 2 to 4 feet in 10 years.

All species for which there are sufficient records grow fastest on the cultivated soils and progressively slower on the heavy maple-basswood or raspberry-covered soils, the better sands and sandy loams, and the jack pine-oak sands. Comparing these four soils on the basis of the height growth of northern white pine in the open and representing its growth on the jack pine-oak sands as 1, the growth on the better sands will be represented by 1.5, on the heavy soils by 2.4, and on the cultivated soils by 3.2. The relations for Norway pine are closely similar. Jack pine shows less relative increase as the soil conditions become more favorable.

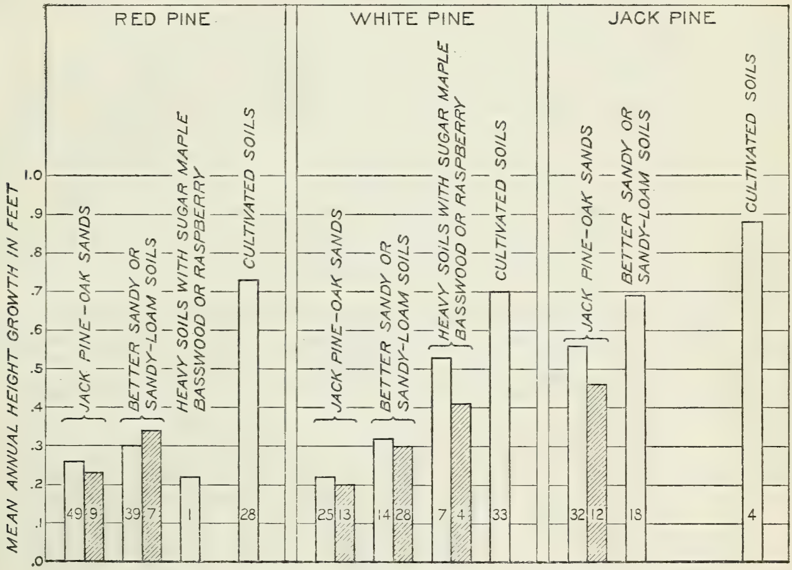

FIGURE 7.—Height growth of plantations on different sites

The exceptionally rapid growth of the planted trees on soils which were cultivated either at the time of planting or years before, is striking. Moreover, this stimulating effect of cultivation outweighs the effect of other soil qualities to such a degree that the average growth of cultivated plantations on the poorest sands is superior to that of uncultivated plantations on the best loamy soils. This superiority in growth is maintained for the first 20 years, but it may not last in the same degree until the trees are mature. Its practical importance is not that it justifies the expense of cultivating, but that it proves abandoned fields to be very favorable sites for planting.

All species on all soils, with the exception of Norway pine on the better sands or sandy loams, grow less rapidly on the average when planted under a cover of over 40 per cent of natural tree growth than they do in the open. If the growth of plantations in the open is taken as 1, the growth of underplantings varies from 0.8 to 0.9. Reed (*53*) in New England has shown in a Norway pine plantation 10 years from seed that the heights of individual trees increased with the amount of sunlight they received, in proportion from 1½ feet in complete shade to 5 or 6 feet in the open.

COMPARISON OF GROWTH IN PLANTATIONS AND IN NATURAL FORESTS

Height growth in the plantations at 10 years compares not unfavorably with natural growth of the same species at that age. The 9 feet for planted jack pine on cultivated soil corresponds to the recorded average figure of 9 feet for natural seedlings (*63, Tables 1, 2, and 4*). The growth of 7 feet for northern white pine plantations in the Lake States on the best cultivated sites and 3 feet for the better sandy or loamy soils corresponds with the New England (*24*) averages of 6 feet on average sites and 4 feet on poor sites. Natural white pine seedlings in northern Wisconsin were found by F. G. Wilson of the Wisconsin Department of Conservation to have an average height of 2½ feet in 10 years, or slightly more than the plantation average for the poorer sandy soils of the Lake States. The growth of 5 or 6 feet at 10 years for Norway pine in plantations, excepting those on the cultivated soils, is less than the 7 feet attained by natural saplings in northern Minnesota (*77, Table 3*), but greater than the 3 feet recorded by Sponsler in northern Wisconsin. The 3-foot height growth of Norway spruce at 10 years compares closely with the average height at that age on medium sites in Europe (*59*).

The comparison between the growth of plantations in the Lake States and natural growth may be extended to the cubic-foot yields of the few older plantations. Northern white pine has an average volume of 800 cubic feet per acre at 20 years, as compared with a volume of 1,350 feet on a poor site, according to the New England yield table (*24*). It may be noted, however, that the New England yields were determined by the measurements of stands which had come up on abandoned fields or cultivated lands. Height growth in cultivated plantations in the Lake States is about twice that on the uncultivated sites, and therefore it would be unreasonable to expect the plantations on uncultivated sites in the Lake States to show as high yields as those given in the New England yield table.

The Norway pine plantations, one 19 years old and two 21 years old, had volumes of 1,580, 1,100, and 2,645 cubic feet per acre, respectively. These yields are much higher than the 800 to 1,000 cubic feet per acre for natural stands at corresponding ages in Minnesota (*77, Table 15*).

Existing plantations of Scotch pine may be taken as indications of the productive capacity of the planting sites in the Lake States. The Scotch pine plantations up to 20 or 22 years show yields comparable with those at corresponding ages on medium and poor sites in Europe (*59*). Planting of this species is not recommended.

The conclusion may be drawn, therefore, that the growth and yields of jack pine and Norway pine plantations in the Lake States will be at least as high as those of natural stands of those species on corresponding sites (*77*). Northern white pine plantations will yield somewhat less than the amounts for a poor site in New England (*24*), but certainly more than those given for Minnesota.

The plantations of white spruce are not old enough to give information on yield, but Kenety (*40*), after making a study of the species in Minnesota, concluded that in plantations "50 cords per acre is a probable yield at the end of 50 years on the proper type of soil." In a commercial planting operation with white spruce in Quebec (*44*) a yield of 38 cords in 50 years was predicted from a study of natural stands.

These figures derived from the growth of natural stands may be regarded as conservative, for the regular spacing between the trees in plantations should promote a more rapid and uniform development of a greater number of trees in the stand and hence a higher yield than would be possible in the more or less irregular natural stands.

Representative yields at merchantable size and age have been estimated for plantations on medium sites, and it is believed that they are conservative for the region. Jack pine should produce on the average 30 cords of pulpwood to the acre at 40 years when the trees average about 5 inches in diameter. Norway and northern white pine will probably require 60 years to produce small saw timber. The yield at 60 years should be at least 15,000 and often 20,000 board feet to the acre. At 60 years the trees would average 9 to 10 inches in diameter with a fair proportion of larger trees up to 18 inches. Indications of the yields of the pines at different ages on different sites are given in Tables 7, 8, and 9.[9] White spruce may be expected to produce 30 cords of pulpwood in 60 years. These ages are as low as they can be placed with any degree of assurance, although under especially favorable conditions it may be possible to grow merchantable crops of these species in shorter periods. The yield of any specific plantation should be estimated for the particular conditions of the planting site.

TABLE 7.—*Yields of Norway pine in natural well-stocked stands*

Age (years)	Total height of average tree on medium site	Diameter breast high on medium site		Yield per acre by site quality		
		Average	Maximum	Good	Medium	Poor
	Feet	*Inches*	*Inches*	*Board feet*	*Board feet*	*Board feet*
5	2	---	---	---	---	---
10	7	1	2	---	---	---
20	20	3	6	---	---	---
30	30	5	10	---	---	---
40	40	7	13	4, 100	2, 000	---
50	50	9	16	9, 400	6, 100	2, 800
60	58	10	18	15, 100	10, 200	5, 300
70	65	12	19	20, 900	14, 300	7, 900
80	72	13	21	26, 500	18, 600	10, 700
90	78	14	22	32, 300	22, 900	13, 700
100	83	15	23	38, 500	27, 400	16, 900
120	92	17	25	50, 800	36, 700	23, 100

Figures in this table are taken or adapted from the publication by Woolsey and Chapman (77) on Norway pine in this region. Board foot yields by Scribner rule.

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[9] These tables, based on data from natural stands for different sites, soils, localities, and degrees of utilization, are not comparable one with another and are only suggestive of the yields of plantations. Their use should be checked on any specific area on which yields are to be estimated.

TABLE 8.—*Yields of northern white pine in natural well-stocked stands*

Age (years)	Average height of dominant trees	Diameter breast high	Yield per acre		Age (years)	Average height of dominant trees	Diameter breast high	Yield per acre	
			Mill tally	Scribner rule				Mill tally	Scribner rule
	Feet	*Inches*	*Board feet*	*Board feet*		*Feet*	*Inches*	*Board feet*	*Board feet*
5	1	------	------	------	60	64	9	33, 600	12, 500
10	4	1	------	------	70	71	10	42, 300	16, 700
20	15	2	------	------	80	78	12	50, 100	20, 000
30	28	4	5, 300	------	90	83	13	57, 000	23, 500
40	42	6	14, 200	------	100	87	15	62, 800	28, 000
50	54	7	24, 100	8, 000	120	------	------	------	39, 700

Figures in this table with the exception of those for yields by Scribner decimal C rule are from Tables 5 and 6 in the bulletin by Frothingham (*24*) already cited. Based on poor site quality New Hampshire white pine, they apparently correspond to good site in the Lake States. Mill-tally yields are based on actual saw cut. Figures in the last column are from Table 31 in the same bulletin for virgin forest in northern Minnesota.

TABLE 9.—*Yields of jack pine*

Age (years)	Total height of average tree on medium site	Diameter breast height on medium site		Yield per acre by site quality					
		Average	Maximum	Good		Medium		Poor	
	Feet	*Inches*	*Inches*	*Board feet*	*Cords*	*Board feet*	*Cords*	*Board feet*	*Cords*
5	3	------	------	------	------	------	------	------	------
10	9	------	2	------	------	------	------	------	------
20	23	3	5	500	10	------	5	------	------
30	34	4	8	3, 000	26	1, 000	17	500	8
40	44	5	9	9, 500	37	3, 500	27	1, 000	16
50	52	6	11	16, 000	43	7, 500	33	2, 500	22
60	58	7	12	20, 500	46	11, 500	36	4, 500	25
70	63	8	12	24, 000	48	15, 000	38	6, 500	27
80	67	9	13	26, 000	50	16, 500	40	8, 000	28

The yields in this table are taken from an unpublished study of Jack Pine Yields by A. E. Wackerman. Maximum diameters are from a publication by Sterrett (*63*). Board-foot yields are based on the international log rule, allowing one-eighth inch for saw kerf.

Under certain conditions, which are discussed later, the yields of timber crops grown to 80, 100, and 120 years are also of interest. Saw timber of Norway and northern white pine is the most promising form of forest crop for these longer periods. Yields of 30,000 board feet to the acre at 80 years, 40,000 board feet at 100 years, and 50,000 board feet at 120 years may be expected.

TABULAR SUMMARY

Most of the details of importance to an individual or company considering forest planting have now been discussed. They are summarized and emphasized in Table 10.

TABLE 10.—*Summary of essential considerations in forest planting*

What to plant [1]		Where to plant	Cost of stock per 1,000 trees	Planting 1 acre, 6 by 6 feet spacing, 1,210 trees		Age of merchantability	Average yields per acre
Kind of tree	Age of stock			Method	Cost		
						Years	*Board feet*
Norway pine	2–0 or 2–1.	Jack pine-oak sands or better sands and sandy loams.	$1. 50–$4. 00	Slit furrow	$6. 00–$9. 00	60–80	10, 000–25, 000
				Slit	7. 00–10. 00		
				Hole	12. 00–15. 00		
Northern white pine	2–1 or 3–0.	Sandy loam and heavier soils.	3. 50–10. 00	Slit furrow	9. 00–15. 00	60–80	10, 000–25, 000
				Slit	10. 00–16. 00		
				Hole	17. 00–25. 00		
							Cords
White spruce	2–1 or 2–2.	Sandy loam and heavier soils.	3. 50–10. 00	Slit furrow	9. 00–15. 00	50–70	20–40
				Slit	10. 00–16. 00		
				Hole	17. 00–25. 00		
Jack pine	1–0	Jack pine-oak sands.	0. 75– 2. 00	Slit furrow	4. 00– 7. 00	35–50	20–35
				Slit	5. 00– 8. 00		
				Hole	10. 00–13. 00		

[1] For stock or specific advice apply to Wisconsin Conservation Commission, Madison, Wis., Michigan Department of Conservation, Lansing, Mich., or Department of Forestry, Michigan State College, East Lansing, Mich.

PROFITABLENESS OF PLANTING

RETURNS FROM PLANTED TREES

One of the most important considerations in planning a program of forest planting is the future money value per unit of wood product. There is, however, no way of predicting accurately for 40 to 60 years or more in the future the value of timber or of any other commodity. Something is known of present stumpage prices in the region and of their trends in the past, which have always been upward. From this knowledge it may be predicted with some assurance that the future prices of standing timber will not be less than the present ones.

Present prices for jack pine range from 50 cents to $2.50 a cord, for white spruce from $1.50 to $6 a cord, and for northern and Norway pine from $8 to $12 a thousand board feet. If only a small increase over the present average prices be assumed, it is certainly conservative to estimate that jack pine will be worth $3 a cord, spruce $5 a cord, and Norway and northern white pine $15 a thousand board feet 40 to 60 years from now. For the Norway and northern white pine plantations grown for 80 to 120 years it has been further assumed that improvement in quality will cause the value of the timber to increase with age. A stumpage value of $20 a thousand board feet has therefore been taken for Norway and northern white pine 80 to 100 years old. Since high-quality white pine has special uses and is in special demand, the future stumpage value (of white pine) at 120 years has been placed at $25 a thousand board feet. Much more optimistic predictions of future values could be made and still be within the limits of probability.

The profitableness of planting, as of any business transaction, lies in the difference between costs and returns. In the growing of a timber crop there is one distinctive feature, however, and that is the long period over which the costs or investment must be carried before returns are realized. The elements which must be considered in the calculation of profitableness are land value, cost of planting, annual expense of fire protection and taxes, number of years to grow the crop, timber yield, and stumpage value. Most of these factors vary with the conditions under which planting is done. It has already been shown how the cost of planting varies with the species, size, and age of the trees planted, soil, and cover conditions, and number of trees planted to the acre. Similarly, the variations in taxes, yields, period of growth, and stumpage values have been discussed.

The different values placed on cut-over land, depending not only on its intrinsic quality but on its location and the opinions of the owner and the local tax assessor, are well known. Some of the good agricultural land and some that is not so good in the northern Lake States is sold for more than $20 an acre. Many owners now would be glad to dispose of large areas for $5 to $10 an acre if they could find purchasers. Others are equally unable to dispose of their land, even at $2 an acre or less. In fact, it may be contended that much of the cut-over bare land has no value at the present time; because (1) the removal of the timber has also removed all sale value, and (2) the land, being nonproductive, has no rental value. Many owners are letting their cut-over lands revert to the State or county for taxes. However, owners prefer to place at least a nominal value on their land, and while it is not believed that cut-over lands in need of planting are worth $2 an acre, that figure has been used as the investment in land on which interest is computed in the calculations of profit. Valuations as high as $5 or even $10, however, are not necessarily prohibitive for forest planting where other conditions are favorable.

PRIVATE PLANTING ON BARE LAND

The ownership of the land, whether public or private, and also the degree to which the timber has been cut, affect several of the elements of profitableness in planting.

To determine how much future stumpage value a timber crop will have to bring in order to earn certain rates of interest on the investment and cost of private planting on bare land, different combinations of costs, taxes,[19] years to grow the crop, interest, return, and yield per acre have been worked out. The detailed figures and an example of the method of calculation will be found in the Appendix, Tables 11 to 18.

It appears from the figures that a paper company could plant sandy lands with 1,210 jack pine seedlings to the acre at a cost of about $5.50, could pay an annual tax of 10 cents an acre plus 5 cents an acre for fire protection, and at the end of 40 years the yield of 30 cords to the acre would have to have a value of only $3.28 a cord to earn 6 per cent compound interest on the investment. This is not much more than jack pine stumpage commands at the present time, and is certainly within reason as an estimate of future price.

If the same company planted white spruce on loamy soils at a cost of $10 an acre and the spruce yielded 30 cords per acre in 60 years, it would have to have a value of $15.79 a cord to earn 6 per cent on the investment. If the company were satisfied with 5 per cent, the stumpage value could be $9.17. At $5.33 a cord, only a little more than the present price, the crop would produce 4 per cent. The higher cost of planting and the longer period needed to grow spruce require a decidedly higher future value than that of jack pine to make it an attractive investment. On the other hand, the special value of spruce for the manufacture of certain grades of paper might easily within 60 years create stumpage values as high as those mentioned. If this white spruce planting was made on land where the taxes were 40 cents instead of 10 cents an acre annually, the future stumpage value to earn 4 per cent would have to be $7.71 instead of $5.33.

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[19] The taxes have been calculated as an annual expense, although modified taxation, such as the yield tax recently included in legislation in Michigan, would necessitate a different method of calculation.

Similar calculations have been worked out for the planting of Norway and northern white pines on different soils at different costs of planting and rates of taxation, to show the future price per thousand which the timber would have to have to earn different rates of interest. Prices vary from the $10.49 necessary to earn 5 per cent on Norway pine planted at a cost of $6.50 an acre and yielding 20,000 board feet to the acre, to the $31.59 a thousand necessary to earn 6 per cent on a $10 planting cost and a 15,000 board feet yield. Although it has been suggested that conservative future values of northern white and Norway pine might be placed at $15 a thousand, $30 or more is well within the limits of possibility for timber of exceptional quality and availability.

Two factors which might modify the calculations have not been included. They are the returns from thinnings made before the final crop is mature and the cost of cleanings or early cuttings to benefit the planted trees. These two operations will be carried out only in certain plantations, and often they woud tend to counterbalance one another. Moreover, little is known about the variable returns and costs which might be involved. Therefore, it has seemed best not to attempt to include them in these general figures, although they should be considered in any specific planting operation.

The accelerating accumulation of compound interest over the long periods of years which are involved in timber growing is primarily responsible for the comparatively poor economic showing for the private owner who starts with bare land. To some classes of owners this will, however, be a matter of little importance. Small property owners, for instance, are setting out many small plantations every year, although they do not expect to harvest the crop themselves. The planting may be a matter of personal interest or an investment for the children or an improvement of the property and its value. The last two are sound economic motives, for there is no question but that a piece of property with a nice grove of young pine timber has a higher sale value than the same piece without the trees. On the other hand, the company that is using timber as a raw product for a manufacturing enterprise and has a supply for only a few years ahead can not be expected to invest heavily in planting a crop which can make satisfactory returns only when it is too late to prolong the life of the enterprise.

PRIVATE PLANTING FOR SUSTAINED YIELD

The large company with a long life is in a more favorable position. Water companies, for example, necessarily own considerable areas of land around their reservoirs or watersheds to insure the purity of the water supply. These lands, to afford the greatest protection, should be forested. Planting of open areas is desirable both for water protection and for the future profit from the timber crop; and the long-term investment is not a deterrent. (Pl. 6, B.) Pulp and paper, mining and railroad companies use timber products in large quantities and many of them own large areas of land. They require a supply of timber as raw material as long as the industry lasts. For their own interests they are or should be in the forest-producing business on a sustained-yield basis.

It is questionable whether the costs of planting by companies of this character should be carried forward at compound interest until the planted timber matures. They are cutting timber each year from their own lands, and there is no reason why a part of the value of the timber that is cut should not be put back into the forest-producing part of the business, to cover the costs of planting an area, which in time will provide a substantial return. In this way the timber that is cut from one-sixtieth of the timber-producing area is replaced each year by the annual growth which has occurred on the whole sixty-sixtieths of the area, and any costs, such as planting, taxes, and protection should logically be paid out of the returns from the cutting.

Once this stage in forest production is reached, and the business organized accordingly, compound interest is done away with, and the profit from growing the timber crop is large and attractive. The company that plants trees on a large scale for timber production and thus places its business on a permanent or sustained-yield basis is not going to stop growing timber after the 40 or 60 years necessary to mature the first crop from bare land. With the matured plantations yielding gross returns (at present values) of $100 to $250 an acre, timber growing becomes a highly profitable part of the business. Since this is so, no good reason remains why this permanently operating company should charge all the costs of preliminary establishment at compound interest to the period of the first crop, for a part can and should be charged to subsequent periods. It requires only a few years after the timber crops begin to be marketed for the excess of net income over current expenses to wipe out the apparent losses involved in the considerable outlay necessary to build up the productive forest capital. The cost of planting on any specific area need be incurred only once; when the plantation matures, reforesting the area can be effected more economically by proper methods of cutting and natural seeding than by planting. Reduction or compensation of the compound interest charges in this way permits a much more favorable showing of the profitableness of planting and growing timber.

If the costs and current expenses of planting and growing a timber crop are not charged at compound interest, the money returns are high. Under the conditions previously outlined, they will be from $72 to $78 an acre for jack pine, from $105 to $131 an acre for white spruce; and from $197 to $300 an acre for Norway and northern white pine. Under still longer rotations for higher yields and values the profits are even more remunerative.

PUBLIC PLANTING

Whereas the private owner can most profitably grow timber in the shortest period necessary to produce a merchantable crop, the public owner derives greater profit from growing the timber over a longer period of years for the production of higher yields, higher quality, and higher values. Planting by the Federal Government, State, county, or town on publicly-owned lands has thus certain distinctive features. In the first place, the cost of fire protection is higher for the State or Federal Government, which must maintain a complete protection organization, than for the private owner who receives the benefit of State-wide protection and adds to it only what is needed to make it thoroughly effective on his lands. Therefore, in determining the profitability of planting on public lands the item of fire protection has been placed at a maximum figure of 15 cents an acre a year. Secondly, public owners pay no taxes,[11] and accordingly that item of annual expense is eliminated. Finally, public investments are made over long periods at low rates of interest. The profit from planting on public lands has, therefore, been computed as the net return per acre, over and above 3 per cent compound interest on the investment, from certain assumed future stumpage values for the timber crop.

Jack pine or spruce crops for pulpwood produce on this basis considerably less than $100 an acre profit, but Norway and northern white pine saw timber show net profits up to $667 an acre. The latter figure is for northern white pine plantings on good soil at a cost of $10 an acre, grown for 120 years to yield 50,000 board feet to the acre with an estimated value of $25 a thousand. This figure may be compared with $131.85 an acre profit for the same timber at 60 years and yielding only 15,000 board feet with a value of $15 a thousand. At 100 years the profit is $547.60 an acre for Norway pine planted on sandy lands at a cost of $6.50 an acre to produce 40,000 board feet valued at $20 a thousand. This is about $9 higher than the profit at 120 years, when it should produce 50,000 board feet to the acre. These examples show clearly that the public owner derives the greatest profit from producing timber of high quality over periods of 100 to 120 years. The public forests are thus in a position to perform a much needed function in supplying the demand for large-dimension and high-quality timber products.

The whole planting question may be summed up for the northern Lake States in the statement that the planting of bare land offers to the private owner an opportunity to realize a reasonable rate of interest on his own investment, and to the public landowner or to the large company in the timber growing business over long periods it promises to be not only an essential source of raw material but also a thoroughly profitable form of investment.

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[11] The payments which Michigan and the Federal Government make to the counties in which State or national forests are situated, in lieu of taxes, come from appropriations for the purpose. Direct reimbursement for these expenses is not anticipated in the returns from the mature crop. Therefore they are not considered as items of expense in the public-planting operations.

A REFORESTATION POLICY

Every year that the 20,000,000 acres of unproductive forest land in the Lake States remains idle means a loss to the region which may be placed conservatively at $20,000,000 a year. The present rate of planting these lands to trees will not reforest them within any reasonable period. Neither the region as a whole nor the States nor the individuals directly concerned can afford to continue to accept this enormous annual loss merely for the lack of an adequate policy to prevent it. What are the essentials of such a policy?

A TIMBER SURVEY

First, as a basis for a policy, a survey should be made of the idle lands in each State to determine their extent, location, present condition, and potential value. The formulation of a reforestation policy is logically a State function, and, therefore, the surveys should be made by the States. The cost of a survey as a preliminary to the formulation of a reforestation policy could be kept very low, probably to not over 1 cent an acre.

A survey would confirm or modify the estimate of 20,000,000 acres in need of planting in the region and determine the correct apportionment of the area between the three States. A survey would settle also the contention sometimes raised that planting is unnecessary because with protection from fire the idle lands are reforesting naturally. Such detailed and accurate information is essential in defining the problem in each State and in determining a planting policy.

The distinction between areas in need of planting and those with sufficient natural tree growth depends on the number of established trees of valuable kinds per acre. Areas with more than 300 trees to the acre would not need to be planted. The planting of areas with 50 to 300 trees per acre could be postponed until areas with less than 50 trees per acre had been planted.

The locations of areas thus classified according to need of planting should be shown on maps in relation to wood-using industries, cities and towns, transportation facilities, and other economic factors.

A survey of the present condition and potential value of the lands should include at least a rough classification of soils and topography to indicate whether the lands are of sufficient fertility and accessibility to justify their early development for agriculture. Large areas may undoubtedly be needed for the production of agricultural crops 100 years from now which until then can be made highly productive through forest planting. The quantity and character of the present forest growth should be noted, together with the soil conditions, since these should indicate the kinds of trees to be planted, enable an estimate of the cost of the planting, permit a rough prediction of the returns from planting trees, and give an index of the fire risk. Notes should also be taken on the taxation of the land, as a basis for evaluating this factor in the cost of planting. Finally, the survey should enable the classification of the idle land on the basis of its value for timber growing.

It has been suggested that there may be parts of the cut-over area in the Lake States which have been burned repeatedly until the naturally poor soils have become so sterile that they will not produce timber. The evidence obtained in this study from existing plantations was that Norway and jack pine will grow good timber crops on the poorest sandy lands. It is probable, however, that some of the swamps and peat soils may be unsuitable for growing timber until the water level is regulated or conditions are otherwise modified to make them more favorable for forest growth. This is a subject which requires and will receive further study.

SELECTION OF AREAS FOR PLANTING

Many factors must be considered in the selection of planting areas, whether they are to be planted by private or public agencies. Highly desirable areas presenting many advantages are unusual and an ordinary selection can not be expected to include more than a part of the desirable qualities. One of the most important considerations which influences location is accessibility to a good market or to the industry which must be supplied with raw material. This is equally important whether the markets are already in existence or are only predicted on the basis of prospective development. The planting area should be located where the fire hazard is naturally low, where good fire protection can be provided, and where sufficient local labor is available both for protection and for planting. The lands should be suitable for the establishment and rapid growth of the species which are to be planted. They should be located where low valuations and low tax rates prevail. They should provide the best combinations of low planting cost with high soil productivity for timber growing. The location and selection of an area with the most favorable combination of all these elements will usually depend on local conditions; but if any one class of land may be said generally to rank high as a prospective planting site it is abandoned fields.

Another important consideration in the selection of areas for planting is their size. A small detached plantation may under favorable conditions be a profitable enterprise simply on the basis of the return from the single timber crop. Much more profitable, however, is the large area with a series of plantations set out over a period of years, which will contribute to a timber-growing operation with a sustained annual yield of wood products. This is the objective in forest planting toward which the wood-using industries, large owners, and public agencies should aim. A large enough area should be obtained for planting to provide for replacing annual yields of timber by natural or artificial reforestation. On this basis the minimum size of planting area will usually be determined by the minimum economic industrial unit which will be supplied from the planted timber.

Two examples may be suggested. A small paper plant consumes from 50 to 100 tons of wood pulp each day, which at the rate of 1¼ cords of pulp wood to the ton is the equivalent of 62 to 125 cords of wood per day. If such a plant is in operation 200 days a year, it will require from 12,500 to 25,000 cords of wood a year. Assuming a yield of 30 cords to the acre, between 400 and 850 acres of land would be cut over each year to supply the plant. If the enterprise is started on bare land a corresponding area should be planted each year. If the wood is jack pine, which can be grown in 40 years, a total of 16,000 to 34,000 acres of land would be needed within a reasonable radius of the paper plant.

Similarly, a small sawmill with a circular saw will consume about 2,000,000 board feet in a year; and a mill with a single band saw will consume 25,000,000 board feet. If the planted timber yields at the rate of 20,000 board feet to the acre, the cut from 100 and 1,250 acres of plantation a year, respectively, will be required to keep these mills running. If it takes 60 years to grow the saw timber, there must be 60,000 and 75,000 acres of land respectively for the two sizes of mill. The areas when worked out in this way are large, but they are the areas that must be available to any wood-using industry which is to be operated on a sustained yield of forest products.

The private owner, for whom it is more profitable to grow timber on a short rotation, may not exceed the areas given for his enterprise, but the public owner can most profitably grow large timber over longer periods and should have forest units considerably larger than those mentioned. If forest areas as large as these are not feasible for individual owners, they are distinctly so for groups of owners in the same locality who combine to plant and grow timber, each on his own land, with the idea of selling a part or all of his product, and thus maintaining permanently the local wood-using industries.

PROTECTION FROM FIRE

The third point in a reforestation policy, and it is perhaps important enough to be placed first, is the provision for effective protection from fire. One of the essentials for any investment is that it be reasonably safe. Unless a fire-protection organization is maintained, no investment in the idle lands of the northern Lake States is safe. Protection is being provided in a measure, and is being improved each year, by the State organizations. It should continue to be strengthened until the area burned over annually is reduced to a fraction of 1 per cent or until the growing timber on the land, whether planted or otherwise, is safe enough to be insurable at reasonable rates.

Actually, the protection of plantations from fire is likely to be much more thorough and effective than it would be on equally valuable areas of natural second growth, because the expenditure of money in planting acts as a strong stimulus to the owner to protect his investment. Therefore, as the number and area of plantations increase, the protection of the plantations, as well as of areas surrounding them, and of the forest lands of the region as a whole, will become more effective.

POLICY FOR STATE-OWNED LANDS

The States should take the lead in the development of a general reforestation policy by working out a policy for the reforestation of State-owned denuded lands. Such a policy was prepared for the State of Michigan in 1915 (*57*) to provide for the reforestation of the State forest land—a comparatively small area at that time.

The total area of idle land in each of the three States is so large that the State governments can not be expected by themselves to reforest more than a part of them. They should, however, by tax title, purchase, or exchange, increase the areas that are now State owned. In advance of acquisition, it should be determined how large an area the State can undertake to plant in a reasonable time; and the acquisition can then proceed until this amount is acquired in blocks suitable for convenient administration. It may be that the States should provide, in connection with the withdrawal of large areas of land from taxation in the poorer northern counties, for the payment of a certain amount to the local communities in which the areas are located, in lieu of taxes. This is being done in Michigan, where the counties receive from the State 5 cents an acre for State forest and other State-owned lands.

The State or any public agency has a particularly favorable opportunity to produce large saw-log timber of high grade and value over long periods of years. In general, private landowners are not likely to undertake the production of high-grade timber, and it is therefore desirable that public agencies plant for that purpose even if somewhat smaller areas must thereby be planted annually or periodically. At the present time, Norway and northern white pine are the species best suited for this purpose, and they should be grown by public agencies to ages of at least 100 and 120 years. The production of high-quality timber at high costs per acre by public agencies must be reconciled, however, with the conflicting desideratum that a maximum area of idle land be planted and made productive as soon as possible. The latter factor has governed in the policy which is being followed on the national forests, where small seedling stock is being planted by the least expensive method, and where only 700 to 900 trees are being planted to the acre, so that a maximum area may be stocked with the limited appropriations available. Under this policy, $9,000 will provide for the planting of 2,000,000 trees on 2,000 to 3,000 acres of land, whereas $9,000 would cover only a little over 600 acres if transplant stock were planted by a more expensive method at the rate of 1,740 trees to the acre.

The Michigan Department of Conservation in planting on the State forests has adhered to the other principle and is planting 1,500 or more trees to the acre, with correspondingly higher costs and less acreage planted with the available funds, in order to produce high-quality timber.

When the area to be acquired and planted by the State has been determined, an annual planting program should be decided upon. Planting should usually be planned to progress from the more to the less accessible parts of the area, since fire protection is usually more effective on accessible areas and the less accessible will receive better protection in subsequent years when the fire protection is improved. The program should provide for planting each year that fraction of the total area that will bring about the planting of the whole area before the year in which the earliest plantation becomes merchantable. For example, supposing one State has 5,000,000 acres of denuded lands of which the State will acquire and reforest one-quarter or 1,250,000 acres. If the policy provides for growing Norway and northern white pine timber on a 100-year rotation, the State should plan to plant each year at least one one-hundredth of the 1,250,000 acres, or 12,500 acres. Presumably the 12,500-acre annual planting would be distributed over 5 or 10 State forests so that there would be not more than 1,200 to 2,500 acres a year to be planted on each forest, an area that can be handled with local labor in any part of the State.

One of the chief obstacles to the expansion of planting programs by State or other public agencies is the difficulty in obtaining appropriations sufficiently large to finance the work. The annual planting of only 12,500 acres of State land in one State as just suggested would cost about $100,000 a year. If the State undertakes to assist counties, local communities, and private owners in reforestation, two or three times that amount would be needed.

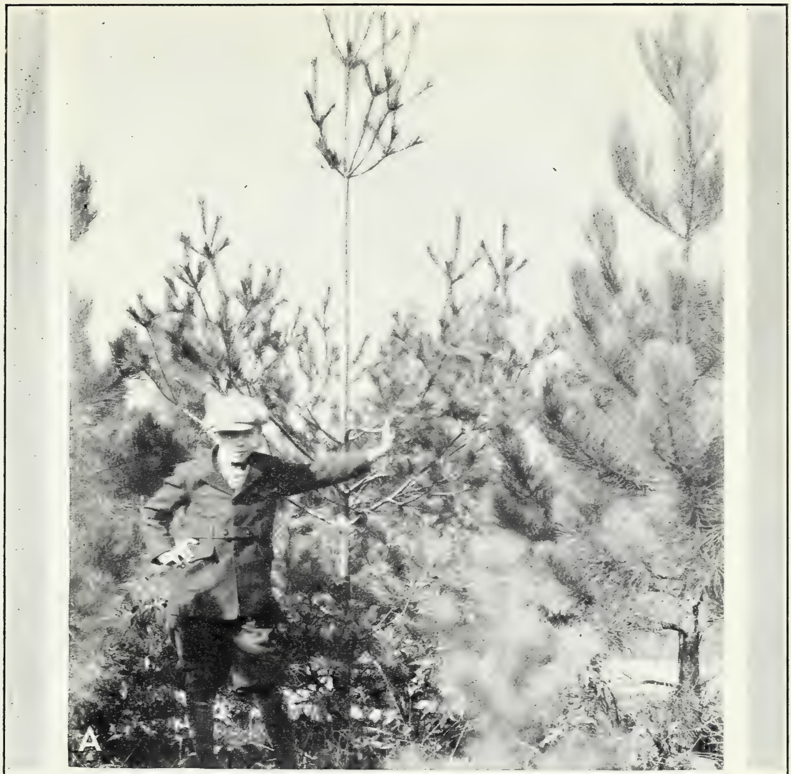
The possibility of reduction or discontinuance of annual or biennial appropriations by legislatures becomes a serious matter in planning and carrying out reforestation policies over long periods of years. Other methods of financing reforestation are, therefore, highly desirable. Some of the Eastern States have issued long-term bonds for forest acquisition and development. This method provides funds to initiate the work on a large scale, the revenue from the forest crops being expected to go far toward paying off the bonds when they mature.

Another plan to finance a State reforestation policy that has been suggested assumes that reforestation is essential for the public welfare and that, therefore, a tax levy of a fraction of a mill on the assessed valuation of the entire State is justified. Wisconsin has passed a constitutional amendment authorizing such a tax levy for the handling and acquisition of State forest land. While it may not be easy to have the necessary constitutional amendment passed, this method of financing a reforestation policy assures permanent and adequate funds to carry out the policy and, therefore, has much to recommend it.

STATE AID FOR LOCAL COMMUNITIES

Since the States can not hope to provide for the planting of all the idle lands directly, they should adopt measures to encourage planting by other agencies. The local communities, counties, cities, and towns are in a position to benefit particularly from the growing of their own timber crops. They are able to borrow money at low rates of interest for long periods of time, and land owned by them is not subject to taxation. Community forests not only provide a highly profitable investment but may serve several other purposes. They protect the watersheds of cities which operate their own water systems; they furnish readily accessible timber crops for community use or sale; and they have high intangible values as park and recreation grounds. Therefore, the communities in forest sections should be encouraged by State aid and otherwise to undertake the planting of idle lands in their localities. In European countries, communal forests are among the most valuable assets and profitable investments of the local communities.

Under a plan of this kind, counties and towns would take title to the land. It might be necessary to purchase some of it to make up suitable blocks. In Wisconsin, tax-title lands revert to the counties and would be available for this purpose. The State could take action in several ways. If necessary, legal permission should be



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A.—A northern white pine planted in 1915 at Trout Lake, Wis., which grew 41 inches in height in 1923. A Norway pine planted at the same time stands at the right

B.—A 21-year-old private plantation in northern Michigan. The Norway pine is 22 feet high, the northern white pine 12 feet, and Norway spruce 9 feet

given the local governments to bond themselves or otherwise borrow money for the acquisition and planting of the lands. The State could furnish planting stock free or at a low cost to communities desiring to plant. A plan has been suggested by which the State would lend money to the local communities at a low rate of interest for a period of 50 or more years, the loan to be secured by a lien on the first returns from the timber crops. The Province of Ontario has adopted a plan by which the counties take title to the land and the State provides planting stock and bears all the expense of planting it. After 30 years during which the State cares for the planted trees, the county has the option (1) of taking over the plantation by paying the State all costs of establishment and maintenance without interest, or (2) the State will buy the land from the county at the price originally paid for it without interest, or (3) the State and county may continue to share jointly in the expense and profits of the timber-growing enterprise. Several counties in Ontario have taken advantage of this plan.

ENCOURAGEMENT OF PRIVATE PLANTING BY STATES

A large increase in private planting is an essential step in solving the gigantic problem of reforestation which exists in each of the three States. Fire protection alone will not solve it. Forest planting and timber growing are clearly to the interest of concerns which require timber as a raw product for a long-lived industry (*1*). It is desirable, however, that the States offer encouragement to owners of forest lands of all classes to plant their idle lands as a matter of State and public interest.

The production and distribution of the trees for planting is of course one means of encouraging forest planting. This is being done in Michigan and Wisconsin and has already proved partially effective. The demand for trees is increasing each year and tends to exceed the supply. For planting within the State the stock is sold at the cost of production. The trees are raised in the same State nurseries in which planting stock for State-owned lands is grown. Large quantities of inexpensive nursery stock are essential if forest planting is to be undertaken on a large scale by private owners.

As a stimulus to forest planting, one State in another part of the country produces and distributes nursery stock to residents of the State at only a nominal charge for packing and shipping. It is a question, however, to what degree planting has been stimulated, and there is the objection that trees which are received free or nearly free are given less care and are valued less highly than those for which a reasonable price has been paid.

In order to encourage the planting of reasonably large areas, it is desirable that the State distribution be restricted to those who are prepared to buy and plant 1,000 or more trees at a time or at least enough for 1 acre. Only in this way will the planting contribute materially to restocking of idle land or to the future timber supply, the two main objects to be accomplished by forest planting.

A second method by which the States can encourage planting by private owners is to provide advice for prospective planters on the kinds of trees to plant, methods of planting, spacing, mixtures, probable yields, and returns for their particular lands. This service should be so extended that advice could be given not only to those who apply for it but also to other owners of denuded forest land, by active efforts to reach and interest them in forest planting. The advice might take the form of preparation of planting plans for individual owners. Assistance and education similar to this is now being provided through the extension foresters at the agricultural colleges in each of the three States. Demonstrations and meetings are planned to reach local groups and thus to interest and stimulate them to undertake planting by their own efforts.

Different forms of cooperation between landowners and the State can be worked out to overcome some of the usual obstacles to private planting. A plan was suggested several years ago for the formation of reforestation corporations by State law for the purpose of growing forests and obtaining a profit from cutting them. The State was to have two-fifths representation on the board of directors. The capital stock was to be based on the land owned. The growing timber would be exempt from taxes during the period of its growth. The State was to loan money, if necessary, to start the planting and to carry the enterprise through the period before the forest crops matured and began to produce income.

More recently, a suggestion has been made, to encourage the reforestation of private land by cooperative agreement between the owners and State, under which the land is set apart for timber growing. The State provides for the planting, protection, and care of the trees and the taxes on the land during the growing period and is partially reimbursed for its expenditures plus a reasonable rate of interest by a 10 per cent yield tax on the sale value of the timber products when they are cut. Actually, to provide for reimbursement and interest would require a yield tax somewhat higher than 10 per cent.

These last two proposals go to extremes in the degree to which they suggest participation by the States in financing and subsidizing forest planting. Their justification is the necessity of reforesting the idle lands in the public interest. There are, however, less extreme modifications possible by which the States would more evenly share the risk and responsibility with the owner and at the same time provide cheap credit for long periods with proper safeguards for the safety of the State's investment.

FOREST TAXATION

The high tax rates on much of the cut-over and denuded land in the Lake States at the present time are considered, and often justly, as serious obstacles to forest planting. As the timber grows and increases in value there is a tendency to increase taxes until they become confiscatory. It is generally conceded that some modification of the existing annual property tax is desirable to remove this obstacle in the way of private owners who wish to plant timber.

Various plans have been incorporated in laws in different States. Michigan and Wisconsin have had for several years forest tax laws providing for reduction or exemption of taxation for small areas or farm wood lots which are devoted to growing trees. Similarly, Minnesota has had a bounty law. These laws have not proved effective in encouraging forest planting. In 1925 Michigan passed a more comprehensive law, and Minnesota and Wisconsin similar laws in 1927. These laws, in general terms, require the owner to pay the equivalent of an annual property tax on his bare land, and defer all taxation of the growing timber until it is about to be cut. At that time a yield tax is levied, which in Michigan is 25 per cent of the total stumpage value of the product to be removed, and in Minnesota and Wisconsin is 10 per cent.

So far no plan of modified forest taxation has proved thoroughly effective or satisfactory, and no agreement has been reached as to the best plan. The Forest Service is making a study of the taxation of forest land at the present time, the results of which will be available later in published form.

NATIONAL AID TO STATES

As a result of the enactment of the Clarke-McNary law in 1924, the National Government through the Forest Service is enabled to cooperate with the States in the advancement of several phases of forestry which are important in a reforestation policy. (1) Cooperation and financial assistance to the States are provided for the better protection from fire of all forest lands within their boundaries. (2) The cooperative study of forest taxation just mentioned, looking toward better adjustment of tax laws to growing timber, is authorized and in progress. (3) Cooperation with States is provided for the collection of seed and the production and distribution of forest-planting stock to encourage the reforestation of denuded lands. All three of the States in the Great Lakes region have made arrangements to take advantage of this cooperation. Finally, cooperation with the States is also provided for advice and assistance to farmers and other owners of land in the growing of timber crops, windbreaks, and shelter belts.

OUTLINE OF A PLANTING POLICY

The reforestation of 20,000,000 acres of land is an enormous problem. How this area is divided between the three States is not certain, but it may be assumed as an example that at least 5,000,000 acres in some one of them will require forest planting to make it productive. On this basis an outline of a State reforestation policy may be sketched.

In order that a series of crops may be secured some of which will mature each year and thus contribute to a sustained annual timber supply, it is desirable to take and it will probably require 50 years to plant these lands. This period is long enough so that some of the earliest plantings will be merchantable for pulpwood before the latest are completed. Assuming, therefore, a 50-year planting program in which to plant the 5,000,000 acres of land, the area to be planted anually will be 100,000 acres. This is seven times the area which was planted by all agencies in all three States during 1926 and obviously involves a large increase in present programs.

Four classes of agencies may logically be expected to do their part in such a program; namely, the State, counties and local communities, the Federal Government, and private owners. If the reforestation task in each State is divided between these four groups in such a way that each of the three public agencies do one-fifth and the private owners two-fifths, there will be 1,000,000 acres to be reforested by each class of public owners and 2,000,000 acres by the private owners over a 50-year period. Evidently, such a program requires large acquisitions of land to be set aside for forest purposes by the States, by the local communities, and by the National Government. In each State it might mean three national forests of over 300,000 acres each, 5 to 10 State forests of 100,000 to 200,000 acres each, and one or more county or town forests of 10,000 to 50,000 acres in each of the northern counties of the three States. The existing State and national forests would serve as centers around which to expand, and other areas would be blocked out by purchase and exchange in order that units of suitable size for administration might be formed. The Federal Government is proposing to acquire 2,500,000 acres in the Lake States for national forests, and a part of these acquisitions will doubtless be lands in need of planting.

Such a program would involve not only land acquisition but a corresponding expansion in the production of nursery stock and in planting. One hundred million trees a year would be required in each State, or more than ten times the largest present forest-nursery output of any one of the States. Present nurseries would have to be enlarged and several additional nurseries established at suitable locations in different parts of each State. With an average cost of planting of $7 an acre, expenditures of $700,000 a year in each State for planting alone would be necessary, of which over $400,000 would be public appropriations, if the three public agencies were to undertake three-fifths of the work.

The organization, administration, and protection of the new forest properties are the essential accompaniment to the program, and this would require a permanent personnel of not less than 100 men in each State. The present State and national forests would become units of the much larger organization. The program would include expenditures for improvements in the way of roads, buildings, and bridges. So large an expansion must be gradual, but it should be as rapid as possible.

This program would have large advantages fully commensurate with its expense. Planting alone would provide work for 1,000 men for 100 days a year—a much-needed opportunity for many of the settlers starting farms in the northern counties.

The presence of the many units of forest property with plantations and organized protection from fire would greatly strengthen the fire-protection work of adjoining areas and of the whole region. Finally, the annual product of the 100,000 acres annual planting, when it became merchantable, would undoubtedly exceed 1,500,000,000 board feet, and this, at only $10 a thousand, would have a gross stumpage value of $15,000,000 or a value when manufactured of at least $50,000,000 each year. Timber production on this scale would support 200 small sawmills or other wood-using industries in each State permanently and would support an equal number of prosperous communities.

APPENDIX

The stumpage values after representative periods of years in which Norway and northern white pine, white spruce and jack pine may be expected to grow to merchantable size, with different combinations of cost of planting plus land value, yields, compound interest rates, and taxes are presented in Tables 11 to 18.

The following example from Table 18 will illustrate the method of calculation of the values in these tables:

Cost of planting jack pine, \$5.50 an acre carried at 6 per cent compound interest for 40 years	\$56.57	(*C*)
Land value at \$2 an acre, carried at 6 per cent compound interest for 40 years	20.57	(*S*)
Annual expense for taxes and fire protection, 15 cents an acre, capitalized at 6 per cent represents a value of \$2.50, and carried at 6 per cent compound interest for 40 years	25.71	(*E*)
Total investment and expenses at 6 per cent for 40 years	102.85	
Deduction for land value, \$2, and capital value of annual expenses, \$2.50, at end of 40 years	4.50	
Cost of growing crop of jack pine	98.35	(*G*)
Value of the crop if it is assumed that the yield of 30 cords an acre in 40 years has a total stumpage value which just pays the cost of growing the crop	98.35	(*Y*)
The stumpage value per cord which will pay 6 per cent compound interest on investment and expenses (\$98.35÷30)	3.28	(*y*)

The same calculation may be expressed algebraically, representing years by *n*, interest rate by *p*, yield per acre of wood products by *b*, as follows:

$$G=(C+S+E)(1+p^n)-(S+E)$$

$$\text{but } G=Y, \text{ and } y=\frac{Y}{b}=\frac{G}{b}$$

$$\text{therefore, } y=\frac{(C+S+E)(1+p^n)-(S+E)}{b}$$

Actually in computing the values in the tables, a value of \$2 for land was used uniformly throughout, although the first columns in each table provide for different combinations of land value with planting cost. The use of a figure other than \$2 for land value, provided land value plus planting cost remain the same, will make a difference of only a few cents in the stumpage values as compared with those given in the tables. In the example just given, if \$1 is used as land value instead of \$2, and the planting is taken as \$6.50 instead of \$5.50, the sum of the two remaining the same, the stumpage value per cord becomes \$3.31 instead of \$3.28, a difference of only 3 cents.

TABLE 11.—*Norway and northern white pine stumpage values per M board feet, 50 years, good sites, 10,000 board feet to the acre*

TO EARN 3 PER CENT

Cost of planting plus land value per acre	Stumpage values per M, classified according to annual taxes in cents per acre, plus 5-cent fire protection				
	15 cents	20 cents	30 cents	45 cents	75 cents
\$5.50	\$3.90	\$4.47	\$5.60	\$7.29	\$10.67
6.50	4.34	4.91	6.03	7.73	11.11
7.50	4.78	5.34	6.47	8.16	11.55
8.50	5.22	5.78	6.91	8.60	11.99
10.00	5.88	6.44	7.57	9.26	12.64
12.00	6.75	7.32	8.44	10.14	13.52
15.00	8.07	8.63	9.76	11.45	14.84
20.00	10.26	10.82	11.95	13.64	17.03
25.00	12.45	13.02	14.14	15.84	19.22

TABLE 11.—*Norway and northern white pine stumpage values per M board feet, 50 years, good sites, 10,000 board feet to the acre*—Continued

TO EARN 4 PER CENT

Cost of planting plus land value per acre	Stumpage values per M, classified according to annual taxes in cents per acre, plus 5-cent fire protection				
	15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	$6.00	$6.76	$8.29	$10.58	$15.16
6.50	6.71	7.47	9.00	11.29	15.87
7.50	7.42	8.18	9.71	12.00	16.58
8.50	8.13	8.89	10.42	12.71	17.29
10.00	9.20	9.96	11.49	13.78	18.36
12.00	10.62	11.38	12.91	15.20	19.78
15.00	12.75	13.51	15.04	17.33	21.91
20.00	16.30	17.07	18.59	20.88	25.46
25.00	19.86	20.62	22.15	24.44	29.02

TO EARN 5 PER CENT

Cost of planting plus land value per acre	15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	$9.25	$10.29	$12.39	$15.53	$21.81
6.50	10.39	11.44	13.53	16.67	22.95
7.50	11.54	12.59	14.68	17.82	24.10
8.50	12.69	13.73	15.83	18.97	25.25
10.00	14.41	15.45	17.55	20.69	26.97
12.00	16.70	17.75	19.84	22.98	29.26
15.00	20.14	21.19	23.28	26.42	32.70
20.00	25.88	26.92	29.02	32.16	38.44
25.00	31.61	32.66	34.75	37.89	44.17

TO EARN 6 PER CENT

Cost of planting plus land value per acre	15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	$14.29	$15.74	$18.64	$23.00	$31.71
6.50	16.13	17.58	20.48	24.84	33.55
7.50	17.97	19.42	22.33	26.68	35.39
8.50	19.81	21.26	24.17	28.52	37.23
10.00	22.58	24.03	26.93	31.29	40.00
12.00	26.26	27.71	30.61	34.97	43.68
15.00	31.79	33.24	36.14	40.50	49.21
20.00	41.00	42.45	45.35	49.71	58.42
25.00	50.21	51.66	54.56	58.92	67.63

If $15 is conservatively estimated as the probable stumpage value of Norway and northern white pine saw timber in 50 years, the figures below $15 (those above the heavy line) indicate that on good sites where they will produce 10,000 board feet per acre in 50 years, they will earn 3 per cent compound interest, where taxes do not exceed 70 cents an acre and where the combined cost of planting and land value is not over $25; 4 per cent in general where taxes are not over 40 cents and the combined cost of planting and land value is not over $15; 5 per cent in general where taxes are less than 25 cents an acre and where the combined cost of planting and land value is not over $10; and 6 per cent where taxes do not exceed 10 cents and where the cost of planting and land value is not over $5.50.

Table 12.—*Norway and northern white pine stumpage values per M board feet, 60 years*

TO EARN 3 PER CENT

Cost of planting plus land value per acre	Site quality [1]	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$2.74	$3.15	$3.97	$5.19	$7.63
	Medium	3.66	4.20	5.29	6.92	10.18
	Poor	5.49	6.30	7.93	10.38	15.27
6.50	Good	3.04	3.45	4.26	5.48	7.93
	Medium	4.05	4.59	5.68	7.31	10.57
	Poor	6.08	6.89	8.52	10.97	15.86
7.50	Good	3.33	3.74	4.56	5.78	8.22
	Medium	4.44	4.99	6.07	7.70	10.97
	Poor	6.66	7.48	9.11	11.56	16.45
8.50	Good	3.63	4.04	4.85	6.07	8.52
	Medium	4.84	5.38	6.47	8.10	11.36
	Poor	7.25	8.07	9.70	12.15	17.04
10.00	Good	4.07	4.48	5.29	6.51	8.96
	Medium	5.42	5.97	7.06	8.69	11.95
	Poor	8.14	8.95	10.58	13.03	17.92
12.00	Good	4.66	5.07	5.88	7.10	9.55
	Medium	6.21	6.75	7.84	9.47	12.73
	Poor	9.32	10.13	11.76	14.21	19.10
15.00	Good	5.54	5.95	6.76	7.99	10.43
	Medium	7.39	7.93	9.02	10.65	13.91
	Poor	11.08	11.90	13.53	15.97	20.87
20.00	Good	7.01	7.42	8.24	9.46	11.91
	Medium	9.35	9.90	10.98	12.61	15.87
	Poor	14.03	14.85	16.47	18.92	23.81
25.00	Good	8.49	8.90	9.71	10.93	13.38
	Medium	11.32	11.86	12.95	14.58	17.84
	Poor	16.97	17.79	19.42	21.87	26.76

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[1] Good sites should yield 20,000 board feet to the acre, medium sites, 15,000, and poor sites 10,000 in 60 years.

If $15 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white pine saw timber at 60 years, the figures less than $15 (those above the heavy line) indicate that it will earn 3 per cent compound interest except where taxes exceed 70 cents, and where the combined cost of planting and land value is over $25; and 4 per cent only where taxes do not exceed 40 cents an acre, where the combined cost of planting and land value is not over $15, and where the site is good.

TABLE 12.—*Norway and northern white pine stumpage values per M feet, 60 years*—Continued

TO EARN 4 PER CENT

Cost of planting plus land value per acre	Site quality	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$4.58	$5.17	$6.36	$8.15	$11.72
	Medium	6.10	6.90	8.48	10.86	15.62
	Poor	9.16	10.35	12.73	16.30	23.44
6.50	Good	5.10	5.70	6.89	8.67	12.24
	Medium	6.81	7.60	9.18	11.56	16.32
	Poor	10.21	11.40	13.78	17.35	24.49
7.50	Good	5.63	6.22	7.41	9.20	12.77
	Medium	7.51	8.30	9.89	12.27	17.03
	Poor	11.26	12.45	14.83	18.40	25.54
8.50	Good	6.16	6.75	7.94	9.73	13.30
	Medium	8.21	9.00	10.59	12.97	17.73
	Poor	12.31	13.50	15.88	19.45	26.59
10.00	Good	6.94	7.54	8.73	10.51	14.08
	Medium	9.26	10.05	11.64	14.02	18.78
	Poor	13.89	15.08	17.46	21.03	28.17
12.00	Good	8.00	8.59	9.78	11.57	15.14
	Medium	10.66	11.46	13.04	15.42	20.18
	Poor	15.99	17.18	19.56	23.13	30.27
15.00	Good	9.57	10.17	11.36	13.14	16.71
	Medium	12.77	13.56	15.15	17.53	22.29
	Poor	19.15	20.34	22.72	26.29	33.43
20.00	Good	12.20	12.80	13.99	15.77	19.34
	Medium	16.27	17.07	18.65	21.03	25.79
	Poor	24.41	25.60	27.98	31.55	38.69
25.00	Good	14.83	15.43	16.62	18.40	21.97
	Medium	19.78	20.57	22.16	24.54	29.30
	Poor	29.67	30.86	33.24	36.81	43.95

If $15 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white pine saw timber at 60 years, the figures less than $15 (those above the heavy line) indicate that it will earn 3 per cent compound interest except where taxes exceed 70 cents, and where the combined cost of planting and land value is over $25; and 4 per cent only where taxes do not exceed 40 cents an acre, where the combined cost of planting and land value is not over $15, and where the site is good.

TABLE 13.—*Norway and northern white pine stumpage values per M board feet, 60 years*

TO EARN 5 PER CENT

Cost of planting plus land value per acre	Site quality [1]	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$7.69	$8.57	$10.34	$12.99	$18.30
	Medium	10.25	11.43	13.79	17.32	24.39
	Poor	15.38	17.15	20.68	25.98	36.59
6.50	Good	8.62	9.51	11.27	13.93	19.23
	Medium	11.50	12.68	15.03	18.57	25.64
	Poor	17.25	19.01	22.55	27.85	38.46
7.50	Good	9.56	10.44	12.21	14.86	20.16
	Medium	12.74	13.92	16.28	19.81	26.89
	Poor	19.11	20.88	24.42	29.72	40.33
8.50	Good	10.49	11.37	13.14	15.79	21.10
	Medium	13.99	15.17	17.52	21.06	28.13
	Poor	20.98	22.75	26.28	31.59	42.20
10.00	Good	11.89	12.78	14.54	17.20	22.50
	Medium	15.86	17.03	19.39	22.93	30.00
	Poor	23.78	25.55	29.09	34.39	45.00
12.00	Good	13.76	14.64	16.41	19.06	24.37
	Medium	18.35	19.52	21.88	25.42	32.49
	Poor	27.52	29.29	32.82	38.13	48.73
15.00	Good	16.56	17.45	19.21	21.87	27.17
	Medium	22.08	23.26	25.62	29.15	36.23
	Poor	33.12	34.89	38.43	43.73	54.34
20.00	Good	21.23	22.12	23.88	26.53	31.84
	Medium	28.31	29.49	31.84	35.38	42.45
	Poor	42.46	44.23	47.77	53.07	63.68
25.00	Good	25.90	26.78	28.55	31.20	36.51
	Medium	34.53	35.71	38.07	41.61	48.68
	Poor	51.80	53.57	57.11	62.41	73.02

[1] Good sites should yield 20,000 board feet to the acre, medium sites 15,000, and poor sites 10,000 board feet in 60 years.

TABLE 13.—*Norway and northern white pine stumpage values per M board feet, 60 years*—Continued

TO EARN 6 PER CENT

Cost of planting plus land value per acre	Site quality	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$12.97	$14.30	$16.97	$20.97	$28.96
	Medium	17.29	19.07	22.63	27.96	38.62
	Poor	25.94	28.61	33.94	41.95	57.93
6.50	Good	14.62	15.95	18.62	22.62	30.61
	Medium	19.49	21.27	24.82	30.16	40.82
	Poor	29.24	31.91	37.24	45.23	61.23
7.50	Good	16.27	17.60	20.27	24.27	32.26
	Medium	21.69	23.47	27.02	32.35	43.02
	Poor	32.54	35.20	40.54	48.53	64.53
8.50	Good	17.92	19.25	21.92	25.92	33.91
	Medium	23.89	25.67	29.22	34.55	45.22
	Poor	35.84	38.50	43.83	51.83	67.83
10.00	Good	20.39	21.73	24.39	28.39	36.39
	Medium	27.19	28.97	32.52	37.85	48.52
	Poor	40.79	43.45	48.78	56.78	72.77
12.00	Good	23.69	25.02	27.69	31.69	39.69
	Medium	31.59	33.37	36.92	42.25	52.91
	Poor	47.38	50.05	55.38	63.38	79.37
15.00	Good	28.64	29.97	32.64	36.64	44.63
	Medium	38.19	39.96	43.52	48.85	59.51
	Poor	57.28	59.95	65.28	73.27	89.27
20.00	Good	36.89	38.22	40.89	44.88	52.88
	Medium	49.18	50.96	54.51	59.85	70.51
	Poor	73.77	76.44	81.77	89.77	105.76
25.00	Good	45.13	46.47	49.13	53.13	61.13
	Medium	60.18	61.96	65.51	70.84	81.50
	Poor	90.27	92.93	98.26	106.26	122.26

If $15 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white pine saw timber at 60 years, the figures less than $15 (those above the heavy line) indicate that it will earn 5 per cent compound interest only where taxes do not exceed 40 cents an acre, where the combined cost of planting and land value is not over $15, and where the site is good or medium; and 6 per cent only where taxes do not exceed 15 cents an acre, where the combined cost of planting nd land value does not exceed $6.50, and where the site is good.

TABLE 14.—*Norway and northern white pine stumpage values per M board feet, 80 years*

TO EARN 3 PER CENT

Cost of planting plus land value per acre	Site quality [1]	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$2.99	$3.45	$4.37	$5.75	$8.50
	Medium	4.19	4.83	6.12	8.05	11.90
	Poor	6.98	8.05	10.20	13.41	19.84
6.50	Good	3.30	3.76	4.67	6.05	8.81
	Medium	4.61	5.26	6.54	8.47	12.33
	Poor	7.69	8.76	10.90	14.12	20.55
7.50	Good	3.60	4.06	4.98	6.35	9.11
	Medium	5.04	5.68	6.97	8.90	12.75
	Poor	8.40	9.47	11.61	14.83	21.26
8.50	Good	3.90	4.36	5.28	6.66	9.41
	Medium	5.47	6.11	7.39	9.32	13.18
	Poor	9.11	10.18	12.32	15.54	21.96
10.00	Good	4.36	4.82	5.74	7.11	9.87
	Medium	6.10	6.75	8.03	9.96	13.82
	Poor	10.17	11.25	13.39	16.60	23.03
12.00	Good	4.97	5.43	6.35	7.72	10.48
	Medium	6.96	7.60	8.88	10.81	14.67
	Poor	11.59	12.66	14.81	18.02	24.45
15.00	Good	5.88	6.34	7.26	8.64	11.39
	Medium	8.23	8.88	10.16	12.09	15.95
	Poor	13.72	14.79	16.93	20.15	26.58
20.00	Good	7.40	7.86	8.78	10.16	12.91
	Medium	10.36	11.00	12.29	14.22	18.07
	Poor	17.27	18.34	20.48	23.70	30.12
25.00	Good	8.92	9.38	10.30	11.68	14.43
	Medium	12.49	13.13	14.42	16.35	20.20
	Poor	20.82	21.89	24.03	27.24	33.67

[1] Good sites should yield 35,000 board feet, medium sites 25,000, and poor sites 15,000 board feet at 80 years.

If $20 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white-pine saw timber at 80 years, the figures less than $20 (those above the heavy line) indicate that it will earn 3 per cent compound interest where taxes are less than 40 cents an acre, except where the combined cost of planting and land value is over $20 and the site poor; 4 per cent in general where taxes are less than 40 cents an acre, where the combined cost of planting and land value does not exceed $15, and where the site is good or medium.

TABLE 14.—*Norway and northern white pine stumpage values per M board feet, 80 years*—Continued

TO EARN 4 PER CENT

Cost of planting plus land value per acre	Site quality	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$5.93	$6.71	$8.29	$10.65	$15.38
	Medium	8.30	9.40	11.61	14.91	21.53
	Poor	13.83	15.67	19.34	24.86	35.88
6.50	Good	6.59	7.37	8.95	11.31	16.04
	Medium	9.22	10.32	12.53	15.84	22.45
	Poor	15.37	17.20	20.88	26.39	37.42
7.50	Good	7.24	8.03	9.61	11.97	16.69
	Medium	10.14	11.24	13.45	16.76	23.37
	Poor	16.90	18.74	22.42	27.93	38.95
8.50	Good	7.90	8.69	10.27	12.63	17.35
	Medium	11.06	12.17	14.37	17.68	24.29
	Poor	18.44	20.28	23.95	29.47	40.49
10.00	Good	8.89	9.68	11.25	13.62	18.34
	Medium	12.45	13.55	15.75	19.06	25.68
	Poor	20.75	22.58	26.26	31.77	42.80
12.00	Good	10.21	11.00	12.57	14.93	19.66
	Medium	14.29	15.39	17.60	20.91	27.52
	Poor	23.82	25.66	29.33	34.84	45.87
15.00	Good	12.18	12.97	14.55	16.91	21.63
	Medium	17.06	18.16	20.36	23.67	30.29
	Poor	28.43	30.27	33.94	39.45	50.48
20.00	Good	15.48	16.26	17.84	20.20	24.93
	Medium	21.67	22.77	24.97	28.28	34.90
	Poor	36.11	37.95	41.62	47.14	58.16
25.00	Good	18.77	19.56	21.13	23.49	28.22
	Medium	26.28	27.38	29.58	32.89	39.51
	Poor	43.80	45.63	49.31	54.82	65.85

If $20 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white-pine saw timber at 80 years, the figures less than $20 (those above the heavy line) indicate that it will earn 3 per cent compound interest where taxes are less than 40 cents an acre, except where the combined cost of planting and land value is over $20 and the site poor; 4 per cent in general where taxes are less than 40 cents an acre, where the combined cost of planting and land value does not exceed $15, and where the site is good or medium.

TABLE 15.—*Norway and northern white pine stumpage values per M board feet, 80 years*

TO EARN 5 PER CENT

Cost of planting plus land value per acre	Site quality[1]	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$11.89	$13.28	$16.06	$20.22	$28.54
	Medium	16.65	18.59	22.48	28.31	39.96
	Poor	27.75	30.99	37.46	47.18	66.60
6.50	Good	13.31	14.70	17.47	21.63	29.96
	Medium	18.63	20.58	24.46	30.29	41.94
	Poor	31.06	34.29	40.77	50.48	69.90
7.50	Good	14.73	16.11	18.89	23.05	31.38
	Medium	20.62	22.56	26.44	32.27	43.93
	Poor	34.36	37.60	44.07	53.78	73.21
8.50	Good	16.14	17.53	20.30	24.47	32.79
	Medium	22.60	24.54	28.43	34.25	45.91
	Poor	37.66	40.90	47.38	57.09	76.51
10.00	Good	18.27	19.65	22.43	26.59	34.92
	Medium	25.57	27.51	31.40	37.23	48.88
	Poor	42.62	45.86	52.33	62.04	81.47
12.00	Good	21.10	22.49	25.26	29.42	37.75
	Medium	29.54	31.48	35.36	41.19	52.85
	Poor	49.23	52.47	58.94	68.65	88.08
15.00	Good	25.35	26.73	29.51	33.67	42.00
	Medium	35.48	37.43	41.31	47.14	58.79
	Poor	59.14	62.38	68.85	78.56	97.99
20.00	Good	32.43	33.81	36.59	40.75	49.08
	Medium	45.40	47.34	51.22	57.05	68.71
	Poor	75.66	78.90	85.37	95.09	114.51
25.00	Good	39.51	40.89	43.67	47.83	56.16
	Medium	55.31	57.25	61.14	66.96	78.62
	Poor	92.18	95.42	101.89	111.61	131.03

[1] Good sites should yield 35,000 board feet, and medium sites 25 000 board feet at 80 years.

If $20 a thousand board feet is conservatively estimated as the probable maximum stumpage value for Norway and northern white pine saw timber at 80 years, the figures less than $20 (those above the heavy line) indicate that it will earn 5 per cent compound interest in general where taxes are less than 25 cents an acre, where the combined cost of planting and land value does not exceed $10, and where the site is good or medium. Even with taxes, planting cost, and land value at a minimum and high yields on good sites, Norway and northern white pine stumpage values of $20 in 80 years will not earn 6 per cent compound interest.

TABLE 15.—*Norway and northern white pine stumpage values per M board feet, 80 years*—Continued

TO EARN 6 PER CENT

Cost of planting plus land value per acre	Site quality	Stumpage values per M, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$24.05	$26.55	$31.54	$39.03	$54.00
	Medium	33.68	37.17	44.16	54.64	75.59
6.50	Good	27.08	29.57	34.56	42.05	57.02
	Medium	37.91	41.40	48.39	58.87	79.83
7.50	Good	30.10	32.59	37.59	45.07	60.04
	Medium	42.14	45.63	52.62	63.10	84.06
8.50	Good	33.12	35.62	40.61	48.09	63.06
	Medium	46.37	49.86	56.85	67.33	88.29
10.00	Good	37.66	40.15	45.14	52.63	67.60
	Medium	52.72	56.21	63.20	73.68	94.64
12.00	Good	43.70	46.20	51.19	58.67	73.64
	Medium	61.18	64.68	71.66	82.14	103.10
15.00	Good	52.77	55.27	60.26	67.74	82.71
	Medium	73.88	77.37	84.36	94.84	115.80
20.00	Good	67.88	70.38	75.37	82.86	97.83
	Medium	95.04	98.53	105.52	116.00	136.96
25.00	Good	83.00	85.49	90.48	97.97	112.94
	Medium	116.20	119.69	126.68	137.16	158.12

Table 16.—*White spruce stumpage values per cord, 80, 60, and 50 years*

TO EARN 3 PER CENT

Cost of planting plus land value per acre	Age	Yield per acre	Stumpage values per cord, classified according to annual taxes in cents per acre plus 5 cents fire protection				
			15 cents	20 cents	30 cents	45 cents	75 cents
	Years	*Cords*					
$6.50	80	40	$2.88	$3.29	$4.09	$5.29	$7.70
	60	30	2.03	2.30	2.84	3.66	5.29
	50	25	1.74	1.96	2.41	3.09	4.44
7.50	80	40	3.15	3.55	4.36	5.56	7.97
	60	30	2.22	2.49	3.04	3.85	5.48
	50	25	1.91	2.14	2.59	3.27	4.62
8.50	80	40	3.42	3.82	4.62	5.83	8.24
	60	30	2.42	2.69	3.23	4.05	5.68
	50	25	2.09	2.31	2.76	3.44	4.79
10.00	80	40	3.82	4.22	5.02	6.23	8.64
	60	30	2.71	2.98	3.53	4.34	5.97
	50	25	2.35	2.58	3.03	3.70	5.06
12.00	80	40	4.35	4.75	5.55	6.76	9.17
	60	30	3.11	3.38	3.92	4.74	6.37
	50	25	2.70	2.93	3.38	4.05	5.41
15.00	80	40	5.15	5.55	6.35	7.56	9.97
	60	30	3.69	3.97	4.51	5.32	6.96
	50	25	3.23	3.45	3.90	4.58	5.93
20.00	80	40	6.48	6.88	7.68	8.89	11.30
	60	30	4.68	4.95	5.49	6.31	7.94
	50	25	4.10	4.33	4.78	5.46	6.81

TO EARN 4 PER CENT

$6.50	80	40	$5.76	$6.45	$7.83	$9.90	$14.03
	60	30	3.40	3.80	4.59	5.78	8.16
	50	25	2.68	2.99	3.60	4.52	6.35
7.50	80	40	6.34	7.03	8.41	10.47	14.61
	60	30	3.75	4.15	4.94	6.13	8.51
	50	25	2.97	3.27	3.88	4.80	6.63
8.50	80	40	6.92	7.60	8.98	11.05	15.18
	60	30	4.10	4.50	5.29	6.48	8.86
	50	25	3.25	3.56	4.17	5.08	6.92
10.00	80	40	7.78	8.47	9.85	11.91	16.05
	60	30	4.63	5.03	5.82	7.01	9.39
	50	25	3.68	3.98	4.59	5.51	7.34
12.00	80	40	8.93	9.62	11.00	13.07	17.20
	60	30	5.33	5.73	6.52	7.71	10.09
	50	25	4.25	4.55	5.16	6.08	7.91
15.00	80	40	10.66	11.35	12.73	14.80	18.93
	60	30	6.38	6.78	7.57	8.76	11.14
	50	25	5.10	5.41	6.02	6.93	8.75
20.00	80	40	13.54	14.23	15.61	17.68	21.81
	60	30	8.14	8.53	9.33	10.52	12.90
	50	25	6.52	6.83	7.44	8.35	10.19

If $5 a cord is conservatively estimated as the probable stumpage value of white spruce in 50 to 80 years, the figures less than $5 (those above the heavy lines) indicate that it will earn 3 per cent compound interest in general where taxes do not exceed 40 cents, where cost of planting and land value does not exceed $20, and where it will produce not less than 25 cords in 50 years or 30 cords in 60 years; where taxes are not over 25 cents, where the cost of planting and land value does not exceed $12, and where it will produce not less than 40 cords in 80 years; and 4 per cent only where taxes do not exceed 25 cents, where cost of planting and land value does not exceed $10 per acre, and where it will produce not less than 25 cords in 50 years or 30 cords in 60 years.

TABLE 17.—*White spruce stumpage values per cord, 80, 60, and 50 years*

TO EARN 5 PER CENT

Cost of planting plus land value per acre	Age	Yield per acre	Stumpage values per cord, classified according to annual taxes in cents per acre plus 5 cents fire protection				
			15 cents	20 cents	30 cents	45 cents	75 cents
	Years	*Cords*					
$6.50	80	40	$11.65	$12.86	$15.29	$18.93	$26.21
	60	30	5.75	6.34	7.52	9.28	12.82
	50	25	4.16	4.58	5 41	6.67	9.18
7.60	80	40	12.88	14.10	16.53	20.17	27.45
	60	30	6.37	6.96	8.14	9.91	13.44
	50	25	4.62	5.04	5.87	7.13	9.64
8.50	80	40	14.12	15.34	17.77	21.41	28.69
	60	30	6.99	7.58	8.76	10.53	14.07
	50	25	5.08	5.49	6.33	7.59	10.10
10.10	80	40	15.98	17.20	19.62	23.27	30.55
	60	30	7.93	8.52	9.70	11.46	15.00
	50	25	5.76	6.18	7.02	8.28	10.79
12.00	80	40	18.46	19.67	22.10	25.74	33.03
	60	30	9.17	9.76	10.94	12.71	16.24
	50	25	6.68	7.10	7.94	9.19	11.70
15.00	80	40	22.18	23.39	25.82	29.46	36.75
	60	30	11.04	11.63	12.81	14.58	18.11
	50	25	8.06	8.48	9.31	10.57	13.08
20.00	80	40	28.37	29.59	32.01	35.66	42.94
	60	30	14.15	14.74	15.92	17.69	21.23
	50	25	10.35	10.77	11.61	12.86	15.37
TO EARN 6 PER CENT							
$6.50	80	40	$23.69	$25.88	$30.24	$36.79	$49.89
	60	30	9.75	10.64	12.41	15.08	20.41
	50	25	6.45	7.03	8.19	9.94	13.42
7.50	80	40	26.34	28.52	32.89	39.44	52.54
	60	30	10.85	11.73	13.51	16.18	21.51
	50	25	7.19	7.77	8.93	10.67	14.16
8.50	80	40	28.98	31.17	35.53	42.08	55.18
	60	30	11.95	12.83	14.61	17.28	22.61
	50	25	7.92	8.50	9.67	11.41	14.89
10.00	80	40	32.95	35.13	39.50	46.05	59.15
	60	30	13.60	14.48	16.26	18.93	24.26
	50	25	9.03	9.61	10.77	12.51	16.00
12.00	80	40	38.24	40.42	44.79	51.34	64.44
	60	30	15.79	16.68	18.46	21.13	26.46
	50	25	10.50	11.08	12.25	13.99	17.47
15.00	80	40	46.17	48.36	52.72	59.27	72.37
	60	30	19.09	19.98	21.76	24.42	29.76
	50	25	12.71	13.29	14.46	16.20	19.68
20.00	80	40	59.40	61.58	65.95	72.50	85.60
	60	30	24.59	25.48	27.26	29.92	35.25
	50	25	16.40	16.98	18.14	19.88	23.37

If $5 a cord is conservatively estimated as the probable stumpage value of white spruce in 50 to 80 years, the figures less than $5 indicate that it will earn 5 per cent compound interest only where taxes do not exceed 15 cents a acre, where cost of planting and land value do not exceed $7.50 an acre, and where it will produce not less than 25 cords per acre in not over 50 years. Even with taxes, cost of planting, and land value at a minimum, white spruce at $5 stumpage value will not earn 6 per cent compound interest.

TABLE 18.—*Jack pine stumpage values per cord, 40 years*

TO EARN 4 PER CENT

Cost of planting plus land value per acre	Site quality[1]	Stumpage values per cord, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$0.97	$1.09	$1.32	$1.68	$2.39
	Medium	1.29	1.45	1.76	2.24	3.19
	Poor	2.58	2.89	3.53	4.48	6.38
6.50	Good	1.09	1.21	1.44	1.80	2.51
	Medium	1.45	1.61	1.92	2.40	3.35
	Poor	2.90	3.21	3.85	4.80	6.70
7.50	Good	1.21	1.33	1.56	1.92	2.63
	Medium	1.61	1.77	2.08	2.56	3.51
	Poor	3.22	3.53	4.17	5.12	7.02
10.00	Good	1.51	1.63	1.86	2.22	2.93
	Medium	2.01	2.17	2.48	2.96	3.91
	Poor	4.02	4.33	4.97	5.92	7.82
12.00	Good	1.75	1.87	2.10	2.46	3.17
	Medium	2.33	2.49	2.80	3.28	4.23
	Poor	4.66	4.97	5.61	6.56	8.46
15.00	Good	2.11	2.23	2.46	2.82	3.53
	Medium	2.81	2.97	3.28	3.76	4.71
	Poor	5.62	5.93	6.57	7.52	9.42

TO EARN 5 PER CENT

Cost of planting plus land value per acre	Site quality[1]	15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$1.37	$1.52	$1.82	$2.28	$3.18
	Medium	1.83	2.03	2.43	3.04	4.24
	Poor	3.66	4.06	4.86	6.07	8.49
6.50	Good	1.55	1.70	2.00	2.45	3.36
	Medium	2.06	2.26	2.67	3.27	4.48
	Poor	4.13	4.53	5.33	6.54	8.96
7.50	Good	1.72	1.87	2.18	2.63	3.53
	Medium	2.30	2.50	2.90	3.51	4.71
	Poor	4.59	5.00	5.80	7.01	9.43
10.00	Good	2.16	2.31	2.62	3.07	3.97
	Medium	2.88	3.09	3.49	4.09	5.30
	Poor	5.77	6.17	6.98	8.18	10.60
12.00	Good	2.52	2.67	2.97	3.42	4.33
	Medium	3.35	3.55	3.96	4.56	5.77
	Poor	6.71	7.11	7.91	9.12	11.54
15.00	Good	3.04	3.19	3.50	3.95	4.85
	Medium	4.06	4.26	4.66	5.27	6.47
	Poor	8.11	8.52	9.32	10.53	12.95

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[1] Good sites should yield 40 cords, medium sites 30 cords, and poor sites 15 cords in 40 years.

TABLE 18.—*Jack pine stumpage values per cord, 40 years*—Continued

TO EARN 6 PER CENT

Cost of planting plus land value per acre	Site quality	Stumpage values per cord, classified according to annual taxes in cents per acre plus 5 cents fire protection				
		15 cents	20 cents	30 cents	45 cents	75 cents
$5.50	Good	$1.94	$2.14	$2.52	$3.11	$4.27
	Medium	2.59	2.85	3.37	4.14	5.69
	Poor	5.19	5.70	6.73	8.28	11.38
6.50	Good	2.20	2.40	2.78	3.36	4.52
	Medium	2.94	3.19	3.71	4.48	6.03
	Poor	5.87	6.39	7.42	8.97	12.06
7.50	Good	2.46	2.65	3.04	3.62	4.78
	Medium	3.28	3.54	4.05	4.83	6.37
	Poor	6.56	7.07	8.10	9.65	12.75
10.00	Good	3.10	3.30	3.68	4.26	5.42
	Medium	4.14	4.39	4.91	5.68	7.23
	Poor	8.27	8.79	9.82	11.37	14.46
12.00	Good	3.62	3.81	4.20	4.78	5.94
	Medium	4.82	5.08	5.60	6.37	7.92
	Poor	9.64	10.16	11.19	12.74	15.83
15.00	Good	4.39	4.58	4.97	5.55	6.71
	Medium	5.85	6.11	6.62	7.40	8.95
	Poor	11.70	12.22	13.25	14.80	17.89

If $3 a cord is conservatively estimated as the probable maximum stumpage value of jack pine in 40 years, the figures less than $3 (those above the heavy line) indicate that it will earn 4 per cent compound interest in general where taxes are less than 40 cents an acre, where the combined cost of planting and land value does not exceed $15 an acre and where the site is good or medium; 5 per cent, in general, where taxes are less than 25 cents an acre, where the combined cost of planting and land value does not exceed $10 an acre, and where the site is good or medium; and 6 per cent, in general, where taxes are less than 25 cents an acre, where the combined cost of planting and land value does not exceed $7.50 an acre, and where the site is good.

COMMON AND SCIENTIFIC NAMES OF TREES MENTIONED IN THE TEXT

Common name	Scientific name
Alder	*Alnus incana* (L.) Willdenow.
American elm	*Ulmus americana* L.
Aspen	*Populus tremuloides* Michx.
Austrian pine	*Pinus nigra*, Arn. var. *austriaca* Schneid.
Balsam fir	*Abies balsamea* Mill.
Balsam poplar	*Populus balsamifera* Linn.
Basswood	*Tilia glabra* Ventenat.
Beech	*Fagus grandifolia* Ehrhart.
Black ash	*Fraxinus nigra* Marsh.
Black cherry	*Prunus serotina* Ehrh.
Black locust	*Robinia pseudoacacia* L.
Black spruce	*Picea mariana* (Mill.) B. S. P.
Black walnut	*Juglans nigra* L.
Blue spruce	*Picea pungens* Engelm.
Box elder	*Acer negundo* L.
Bur oak	*Quercus macrocarpa* Michx.
Butternut	*Juglans cinerea* L.
Douglas fir	*Pseudotsuga taxifolia* (Lam.) Britton.
Eastern cottonwood	*Populus deltoides* Marsh.
Eastern hemlock	*Tsuga canadensis* (Linn.) Carr.
Eastern red cedar	*Juniperus virginiana* L.
Engelmann spruce	*Picea engelmannii* Engelm.
European larch	*Larix decidua* Mill.
Green ash	*Fraxinus pennsylvanica lanceolata* Sarg.
Hardy catalpa	*Catalpa speciosa* Warder.
Honey locust	*Gleditsia triacanthos* L.
Jack oak	*Quercus ellipsoidalis* E. J. Hill.

Common name	Scientific name
Jack pine	*Pinus banksiana* Lamb.
Lodgepole pine	*Pinus contorta* Loud.
Noble fir	*Abies nobilis* Lindl.
Northern white cedar	*Thuja occidentalis* L.
Northern white pine	*Pinus strobus* L.
Norway pine	*Pinus resinosa* Solander.
Norway spruce	*Picea abies* (L) Karst.
Paper birch	*Betula papyrifera* Marsh.
Pin cherry	*Prunus pennsylvanica* Linn.
Red maple	*Acer rubrum* L.
Red oak	*Quercus borealis maxima* Ashe.
Red spruce	*Picea rubra* Link.
Rock elm	*Ulmus racemosa* Thomas.
Russian poplar	*Populus petrowskiana* Schroeder.
Scarlet oak	*Quercus coccinea* Muench.
Scotch pine	*Pinus sylvestris* L.
Silver maple	*Acer saccharinum* L.
Sugar maple	*Acer saccharum* Marsh.
Sycamore maple	*Acer pseudoplatanus* L.
Tamarack	*Larix laricina* (Du Roi) Koch.
Western white pine	*Pinus monticola* D. Don.
Western yellow pine	*Pinus ponderosa* Laws.
White ash	*Fraxinus americana* L.
White oak	*Quercus alba* L.
White spruce	*Picea glauca* (Moench) Voss.
Willow	*Salix* sp.
Winged elm	*Ulmus alata* Michx.
Yellow birch	*Betula lutea* Michx.
Yellow poplar	*Liriodendron tulipifera* L.

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